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Butter: Its Composition and Deterioration.

(*Continued.*)

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THE GROWTH OF MICRO-ORGANISMS IN BUTTER AND THE EFFECT OF THE COMPOSITION OF THE BUTTER AND OF STORAGE CONDITIONS.

If one takes into consideration all the conditions affecting the experiments, it will be found that but little reliable data is available regarding the effect of any single controlling factor on the growth of one type of organism. Let us enquire how this comes about.

In the first place it should be noted that the so-called "bacteria counts" are counts of bacteria plus percentages, generally undetermined, of yeasts and possibly moulds. Media used for the enumeration of the numbers of bacteria do not inhibit the growth of yeasts and moulds and, unless separate counts are made simultaneously of the numbers of these latter, one cannot say to what extent they contribute to the total count. Grimes and Hennerty, in their study of the quantitative changes in the microbiological flora of sweet-cream salted butter stored at 15°F., noted that in many cases the yeasts had so far increased as to make it impossible to obtain bacterial counts (70).

In the case of yeast and mould counts, it is only since the work of Hood and White that the conditions for obtaining true yeast and mould counts have been recognised (80, 81). They found that media for the enumeration of yeasts and moulds in butter should have the acidity adjusted to pH 3.5 and the plates should be incubated for 5 days at a temperature of 25°C. In consequence of the lack of appreciation of these conditions most of the work on the growth of yeasts and moulds is unreliable, the counts in many cases being probably largely comprised of acid-tolerant bacteria.

The Growth of Moulds in Butter.

Macy studied the influence of various factors upon the growth of moulds in butter (82). The factors affecting growth which are controllable by the butter-maker are salt and temperature, and the effect of these factors will be particularly noted. Macy reviews a great deal of literature on this subject, but only a few pertinent cases will be mentioned here.

Gripenberg found that moulds (*Penicillium sp.* and *Trichosporium sp.*) would grow in butter serum containing 18% and 20% of salt for as long as 5 to 6 months (83). When the serum was diluted growth was much better. He made hanging-drop preparations of butter serum containing 0, 10 and 25% salt and inoculated them with *Penicillium crustaceum* and *Trichosporium collae*. In the unsalted serum growth was active after 9 days for both types; with 10% salt the growth was slight; with 25% salt no growth was evident.

Fettick prepared sterile butter samples containing 0, 0.5, 1, 2, 3, 4, 5 and 6 per cent. salt (84). Series of these samples were inoculated with the moulds *O. lactis*, *Mucor mucedo* and *P. glaucum* and stored for one week in a dark place at 17°C. The growth of all three species decreased with increase in the percentage of salt, and no growth appeared in samples containing 4% or more salt. He also followed the growth of *O. lactis* and *P. glaucum* in unsalted butter and in butter containing 3% salt. In the salted butter the moulds decreased immediately and disappeared within 2 months; in the unsalted material they increased steadily.

Boeckhout and de Vries studied the growth at 21°C. of *Hormodendrum sp.* in butter containing 0, 2, 2.5 and 3 per cent. salt (85). Growth only occurred in the unsalted butter.

Macy carried out experiments to determine the effect of the salt content of butter upon the growth of moulds (82). The following table shows the results obtained when the moulds were inoculated directly into butter and the butter stored for six weeks at 10°C. in a humid atmosphere.

EFFECT OF SALT UPON THE GROWTH OF MOULD CULTURES IN STERILE BUTTER.

Time	1 Week.				3 Weeks.				6 Weeks.			
Per cent. salt	0	1·2	2·6	2·9	0	1·2	2·6	2·9	0	1·2	2·6	2·9
Per cent. salt in brine	0	7·1	13·9	15·3	0	7·1	13·9	15·3	0	7·1	13·9	15·3
Culture												
Alt. humicola	—	—	—	—	+	—	—	—	++++	++	+	+
A. flavus	—	—	—	—	—	—	—	—	—	—	—	—
A. niger	—	—	—	—	—	—	—	—	—	—	—	—
H. cladosporioides	—	—	—	—	+	—	—	—	+++	++	+	+
M. sylvaticus	—	—	—	—	—	—	—	—	+	+	—	—
O. lactis var. A.	—	—	—	—	—	—	—	—	—	—	—	—
O. lactis var. B.	—	—	—	—	—	—	—	—	—	—	—	—
P. biforme	+	—	—	—	++	+	—	—	++++	++	++	++
P. expansum	+	—	—	—	++	+	—	—	+++	++	++	++
R. nigricans	—	—	—	—	—	—	—	—	+	—	—	—
Check	—	—	—	—	—	—	—	—	—	—	—	—

The moulds studied were species isolated from butter samples.

From his review of the literature Macy notes that:—"In a general way it appears evident that low temperatures impede the development of moulds in butter but experimental evidence for different species and specific temperatures is lacking. Butter has been found to be mouldy even at relatively low temperatures when stored for sufficient periods of time."

That temperature has a marked effect upon microbiological growth is well known, and moulds are no exception to this rule. Macy carried out experiments to verify the effect of temperature particularly in the case of mould growth in butter (82). The following table shows Macy's results when the moulds studied were inoculated into sterile sweet cream, incubated for four days at 20°-25° C., and the cream made into butter. Representative data only is selected.

EFFECT OF TEMPERATURE UPON THE GROWTH OF MOULD CULTURES IN BUTTER MADE FROM INOCULATED CREAM.

		Extent of growth, high humidity, after—								
	Per cent. salt.	2 Weeks.			4 Weeks.			6 Weeks.		
Temperature °C.:		20°.	10°.	0°.	20°.	10°.	0°.	20°.	10°.	0°.
Culture—										
Alt. humicola	0	—	—	—	—	—	—	—	—	—
	1·5	—	—	—	—	—	—	—	—	—
A. flavus	0	+	—	—	+ +	—	—	+ +	—	—
	1·4	+ +	—	—	+ + +	—	—	+ + +	—	—
	2·2	+ + +	—	—	+ + +	—	—	+ + +	—	—
	4·0	+ +	—	—	+ +	—	—	+ +	—	—
A. niger	0	+	—	—	+	—	—	+	—	—
	1·5	+ +	—	—	+ + +	—	—	+ + +	—	—
	2·5	+ +	—	—	+ +	—	—	+ +	—	—
	4·5	+ +	—	—	+ +	—	—	+ +	—	—
H. cladosporioides	0	+ + +	+ +	+	+ + +	+ + +	+ +	+ + +	+ + + +	+ +
	1·6	+ +	+ +	—	+ +	+	+	+ +	+	+
	2·7	+ +	+	—	+	+	—	+	+	—
	3·3	+	+ +	—	+	+	—	+	+	—
M. sylvaticus	0	+ +	—	—	+ +	—	—	+ +	—	—
	1·1	—	—	—	—	—	—	—	—	—
O. lactis var. A.	0	—	—	—	—	—	—	—	—	—
	1·4	—	—	—	—	—	—	—	—	—
P. uiforme	0	+	+	+	+	+ +	+ +	+	+ +	+ +
	0·7	—	+	—	—	+ +	—	—	+ +	+
	2·3	+	—	—	+	+ +	—	+	+ +	—
	3·1	+	—	—	+	—	—	+	—	—
P. expansum	0	+ +	+	—	+ +	+ +	—	+ +	+ +	—
	1·3	+ +	+	—	+ +	+ +	—	+ +	+ +	—
	2·2	+ +	+	—	+ +	+ +	—	+ +	+ +	—
	3·0	+	+	—	+	+ +	—	+	+ +	—
R. nigricans	0	—	—	—	—	—	—	—	—	—
	1·3	—	—	—	—	—	—	—	—	—

Macy's discussion of his results with salt and temperature in general reads: "The amount of salt in butter is unquestionably an important factor influencing the growth of moulds. The results presented in the foregoing pages demonstrate that the effect of salt upon growth depends especially upon the species of moulds, the amount of moisture, and the temperature. In accordance with many previous investigations, *O. lactis* was checked by a slight concentration of sodium chloride in the substrate. The disappearance of this fungus in salted butter may be explained on this basis. The species of *Mucor and Rhizopus* studied were only slightly more resistant to salt and consequently would not be expected to be important in the moulding of salted butter. *Aspergillus niger* and *Aspergillus flavus* are resistant to high salt concentrations, but when butter was kept at temperatures below 10°C. growth was impeded. For this reason, their importance as causes of moulding in butter stored at the usual commercial temperatures is slight. The other moulds studied—*Alternaria, Hormodendrum,* and *Penicillium*—were found to be capable of growing in high salt concentrations and at the lower temperatures. As these species produce the most marked changes in the appearance, flavour, and aroma of butter when they are able to develop, they are of major importance. The species of *Alternaria* and *Hormodendrum* studied produced dark green, almost black, smudgy areas. Their mycelia spread considerable distances from the point of infection, both along the surface and to considerable depths in the butter. The species of *Penicillium*

used did not mar the appearance of butter particularly, although in some cases sufficient green fruiting bodies were formed to give a slight, dusty discolouration of the surface. The cultures of *Penicillium* affected largely the flavour and aroma. Butters in which these species were growing became distinctly cheesy in flavour and odour, and in these characters suggested Roquefort cheese. In any consideration of the effect of salt on the growth of mould in butter, the concentration of the salt in the droplets of water within the butter must be taken into account. Even though a gravimetric analysis of butter may indicate a high salt content, it is important to know how much water is present to carry this salt. Some of the experiments reported in the preceding pages illustrate this point. If the percentages of water and salt are both high, the concentration of salt in the water may not be any higher than if both are low. Equally, if the water content is low and the salt content moderately high, the brine may be highly concentrated. Then, also, the salt may be unevenly distributed in the minute droplets of moisture within the butter. Some may represent a strong and others a weak brine. The number of conidia in butter, even under extreme conditions, will seldom be large and never considerable in proportion to the number of water droplets. It is conceivable that a conidium may be allocated to a droplet of water containing little or no salt and an abundant supply of food and accordingly be able to germinate and develop without restraint. Only one such instance would lead to serious consequences as far as moulding is concerned. Thus the effect of salt on the growth of mould on butter will depend entirely upon the relative concentration of the salt in the droplets in which the mould spores, or mycelium, may be located. This may partly explain the moulding of salted butter, even though the composition of the butter and type of mould may at first have been considered sufficient reasons for expecting protection against such a contingency."

The following table is taken from an earlier paper by Macy (86). It shows data for mould counts secured on 2,700 lots of butter of varying composition, age and quality and from many creameries, taken at random from 60 lb. tubs as they were shipped to the market.

RELATION OF MOULD COUNTS TO SALT CONTENT OF BRINE.

Salt Content of Brine.	Distribution of Mould Counts in each Group.			
	10 or less.	11 to 50.	51 to 100.	101 or more.
%	%	%	%	%
Unsalted	7·0	6·1	8·0	78·9
0·4— 7·9	30·5	21·7	8·7	39·1
8·0— 8·9	42·2	44·4	6·7	6·7
9·0— 9·9	46·9	33·3	10·4	9·4
10·0—10·9	47·2	34·7	6·8	11·3
11·0—11·9	44·0	42·0	8·2	5·8
12·0—12·9	51·3	36·6	5·8	6·3
13·0—13·9	47·7	33·0	7·9	5·4
14·0—14·9	53·4	35·6	6·4	4·6
15·0—15·9	53·9	35·3	6·0	4·8
16·0—16·9	57·7	34·0	3·6	4·7
17·0—17·9	48·5	38·2	5·9	7·4
18·0—18·9	63·9	16·7	16·7	2·7
19·0—26·9	59·1	36·4	0·0	4·5

Macy has noted a factor worthy of consideration in the packing of butter (82). This is that all the moulds which he studied, and which may be considered fairly representative of the types commonly found in butter, will not grow in the absence of air. In view of this fact it is desirable that butter be wrapped in paper impervious to air and with the paper in the closest possible contact with the butter, so that surface moulding of the butter may be minimised. Macy also noted that a humid atmosphere was essential for growth. In no case studied did moulds grow on the surface of butter when the humidity of the atmosphere was as low as 70-75%. Here again the value of an impervious wrapper in contact with the surface of the butter is indicated.

The Growth of Bacteria in Butter.

According to its concentration in solution, salt may exert either a stimulating or an inhibitory action upon the growth of bacteria. At 0.5 molar concentration it exerts a stimulating effect upon bacterial growth, but at 3 molar concentration it exerts an inhibitory effect. (0.5 molar solution contains 2.93 gms. sodium chloride in 100 mls., 3 molar solution contains 17.55 gms. sodium chloride in 100 mls.)

Salt also widens the range of pH values of media within which bacteria will grow. The following data showing the beneficial effects of low concentrations of salt upon the growth of *B. coli* is cited by Topley & Wilson (92).

Media.	pH Value.	Turbidity Appears (in hrs.).
Peptone water	5·3	36
Peptone water, 0·2 molar NaCl	5·3	4
Peptone water	8·3	7
Peptone water, 0·2 molar NaCl	8·3	3½
Peptone water	4·8	No growth
Peptone water, 0·2 molar NaCl	4·8	20

An industrial fermentation where the effect of salt upon microbial growth has been well studied is the pickling of cucumbers or gherkins. When the fruits are received at the pickling factories they are covered with a very varied microbial flora. Before pickling takes place the only preparation given them is, perhaps, a preliminary washing to remove the greater part of the adhering soil and dust. They are then transferred to the pickling vats. The pickling brine, being made from rough salt and fresh water, also contains, initially, a very varied microbial flora. The end to be achieved is a selective growth of the lactobacilli present on the fruit to produce a clean conversion of the carbohydrates of the fruit to lactic acid.

The selective growth of the lactobacilli is achieved by careful adjustment of the salt content of the brine. The concentration of the brine must be maintained at 10.5% salt if the growth of putrefactive organisms is to be prevented and the growth of the lactobacilli permitted.

If it is necessary to store the fruit in the brined condition when the fermentation has been completed, the salt concentration of the brine is increased to 16% to prevent all further bacterial growth.

In butter containing 16% moisture the salt contents, to bring the concentration in the serum to the above figures, will be 1.7% and 2.6% respectively.

In the case of the specific defect known as "surface taint" of butter in America, and which is similar to, if not identical with, the defect known as "rabbit-O" in Australia, Derby & Hammer found that a salt content of 1.5% in butter having a moisture content of 13.2% prevents the development of the defect (93). In butter containing 16% moisture the equivalent salt content is 1.82% to give the same brine concentration of 11.36%.

From a survey of the literature it may be seen that the influence of salt on the keeping quality of butter varies according to the temperature of storage. When the butter is stored at temperatures which permit microbial growth, the effect of salt in restraining growth is important. When held at temperatures which tend to inhibit bacterial growth, the effect of salt is of less importance, and, in fact, because the salt enhances all flavours, including undesirable flavours, and because salt in the presence of other factors may accelerate chemical decomposition as explained previously, the keeping quality of salted butter may be inferior to the keeping quality of the same butter unsalted. However, it is a fact that butter after sale is quite generally held at temperatures which permit microbial growth, and furthermore, it has been pointed out previously that salt itself is not a cause of butter deterioration. It follows, therefore, that a knowledge of the correct percentage of salt which should be added to butter to obtain satisfactory inhibition of microbial growth is most important.

A number of reports are available indicating the effect of salt upon the "total microbial count" of butter (sometimes wrongly called "total bacterial count").

The following data is taken from a paper by Spitzer and Parfitt (59). The data was obtained by examination of 183 samples of butter submitted for competition and held in cold store for approximately three months.

The effect of salt upon the per cent. of butters increasing in numbers of micro-organisms during storage.

Per cent. salt in brines	0–5	5.1–10	10.1–15	15.1–20
"Total bacteria" ..	70.00	67.01	48.55	15.79

The following data is taken from a paper by Macy (94). The samples were stored in most varied conditions.

THE EFFECT OF SALT CONTENT ON CHANGE IN "BACTERIAL" COUNT DURING STORAGE OF BUTTER.

Salt Content.	Total Samples.	Change of "Bacterial" Count.		
		Increased.	No Change.	Decreased.
		%	%	%
0·0	62	72·1	0·0	27·9
0·4—0·95	123	17·7	0·0	82·3
1·0—1·9	207	27·5	0·5	72·0
2·0—3·4	213	26·3	1·9	71·8

The following data is taken from the work of Washburn & Dahlberg (5). Samples of butter prepared from ripened cream were stored at -15°F. for 284 days and for a further 20 days at 58-60°F. A salted sample and an unsalted sample were prepared from each churning.

Churn Number.	Per cent. Salt.	"Bacteria" in thousands per cc.			
		Initially.	113 days at —15° C.	284 days at —15° C.	284 days at —15° C., 20 days at 56–60° C.
3	0	3,756	100	280	2,880
	1·72	3,248	360	560	96
2	0	944	28	164	2,000
	2·07	3,984	376	108	48
6	0	10,560	26	176	1,600
	2·41	3,464	54	272	10
1	0	...	320	448	5,280
	2·51	...	672	...	4
4	0	5,466	44	52	1,360
	3·27	700	52	224	17
5	0	9,862	240	432	2,560
	3·79	2,250	456	2,320	144

The data illustrates the generally accepted opinion that the organisms die off more rapidly in unsalted than in salted butter when the butter is stored at low temperatures, and also the inhibiting effect of salt upon microbial growth when the material is held at temperatures which do not inhibit bacterial growth.

Consistent with the fact that salt inhibits growth when other conditions are suitable for the growth of bacteria in butter, is the increased deterioration which takes place in unsalted material. The effect of salt in inhibiting the production of "surface taint" has already been mentioned. The most common defects in unsalted butter are probably the "cheesy" odours and flavours. The work of Herreid *et alia* indicates that such defects are developed in unsalted butter because of the action of micro-organisms (3). To consider a more recent publication, Jacobsen noted that the flavour deterioration was more rapid in unsalted butter held at 21°C after storage at —25°C, than in salted butter similarly treated (95).

Attempts have been made to correlate the types of organisms present in butter with the grade of cream from which the butter was made and with the deterioration taking place during storage.

Hedrick made experiments to determine the extent of the correlation between the organisms found microscopically in the butter serum and the grade of cream from which the butter was made (98). 524 butter samples were studied, 143 prepared from excellent cream, 125 from good cream, 159 from fair cream, and 97 from poor grade cream. The percentages in each group correctly correlated with the grade of cream were 91.6 per cent., 58.4 per cent., 42.7 per cent., and 53.6 per cent. respectively. This seems to indicate that the microscopic examination was fairly accurate in distinguishing butter made from excellent cream, but for lower grades it was not a reliable method. The presence of "starter" organisms or holding the samples for as long as 30 days did not materially alter the percentage graded correctly. (It is necessary to note that the butter was salted and that therefore little bacterial growth would be expected in storage).

"The two apparent reasons for not being able to determine the 'good,' 'fair' and 'poor' grades as accurately as the 'excellent' were:—

(1) Low scoring cream was not always the result of bacteriological action but was caused by chemical action and absorbed feed flavours.

(2) The other reason was the contamination by organisms subsequent to pasteurisation of cream and during the churning process."

Examination of Hedrick's data shows that of the number of samples which were wrongly graded many were misplaced by only one grade. Unfortunately, he has not shown how accurate the grading would have been had butter samples prepared from cream graded low because of feed taints been excluded. Had this been done it seems likely that the conclusion reached would have been that certain bacteriological pictures can be associated with low grade cream only if the poor quality is due to bacterial decomposition.

Nelson studied the flora found microscopically with a view to predicting the keeping quality of butter when stored for 21 days at 21°C (99). He found that clumps of well-stained thin rods were generally a sure sign that deterioration would take place, particularly in the case of unsalted butters. He was able to predict the keeping quality correctly in 96.4 per cent. of the commercial, salted samples; in 79.6 per cent. of unsalted and 84.9 per cent. of the exhibition butter samples.

Flake and Parfitt found that "there was a limited relation between the microscopic picture and the decrease in score (100). In general, it was found that large numbers of rod-shaped organisms were found in butter having poor keeping quality." The butter, which was salted, was stored for 10 days at 15.5°C.

It has long been known that some species of organisms hydrolyse fat; other species produce extensive protein decomposition. A search of the literature gives no conclusive evidence that the numbers of either lipolytic or caseolytic organisms can be correlated with butter deterioration. It seems to the writer that the extent to which any species is undersirable, taking, for instance, caseolytic species, will be dependent upon its ability to grow in the conditions obtaining in the butter and upon the nature of the protein decomposition products which it produces, and not merely upon its ability to break down protein in an unspecified manner. Also it seems highly probable that the extent to which a lipolytic specie will be undesirable in butter will be dependent upon the nature of the products formed and its adaptability to conditions in the butter. Certainly the proposed tests for caseolytic and lipolytic species give no indication of the adaptability of the organisms to the conditions in butter or the type of decomposition products which they produce.

In connection with tests for lipolytic species, the remarks made by the writer previously in connection with the flavours and odours of the fatty acids should be remembered.

Stark & Scheib studied a large number of proteolytic and caseolytic species of bacteria isolated from butter (101). They concluded: "Those groups occurring in numbers large enough to be of probable significance in the spoilage of butter were Gram-negative rods, Gram-negative micrococci, Gram-positive sarcinae, and Gram-positive non-spore-producing rods. In butters supporting the growth of large numbers of bacteria, only the Gram-negative rods were regularly present in large enough numbers to be of importance in the spoilage of all the butters tested."

Guthrie *et alia*, as a result of their experiments, concluded: "In the absence of other spoilage factors, a direct correlation seems to exist between the number of fat-splitting and casein-digesting bacteria and the keeping quality of the butter" (102). Their data does not seem to bear out this statement.

Flake & Parfitt presented the following data in connection with samples of salted butter made from sour cream which were stored for 10 days at 15.5°C. (100).

RELATION OF PROTEOLYTIC BACTERIAL COUNT TO DROP IN SCORE OF BUTTER HELD FOR 10 DAYS AT 15·5° C.

	Drop in Score (points).							
	0	1	1·5	2	2·5	3	3·5	4 or >
Number of Samples	22	9	18	22	8	12	4	6
Log. av. of proteolytic counts	9,250	2,350	5,000	31,000	23,000	7,500	4,000	32,000
Prot. counts of 100,000 or more.%	4·5	11·0	5·6	36·4	50·0	16·7	25·0	50·0

RELATION OF LIPOLYTIC COUNT ON TRIBUTYRIN MEDIUM TO DROP IN SCORE OF BUTTER HELD FOR 10 DAYS AT 15·5° C

	Drop in Score (points).							
	0	1	1·5	2	2·5	3	3·5	4 or >
Number of Samples	16	6	9	10	5	9	3	5
Log. av. of counts	120,000	150,000	130,000	890,000	480,000	590,000	1,350,000	680,000

RELATION OF LIPOLYTIC COUNT ON NILE-BLUE-SULPHATE MEDIUM TO DROP IN SCORE OF BUTTER HELD FOR 10 DAYS AT 15·5° C.

	Drop in Score (points).							
	0	1	1·5	2	2·5	3	3·5	4 or >
Number of samples	22	9	17	22	9	12	4	....
Log. av. of counts	7,400	9,200	21,500	117,500	17,000	38,000	26,000	2,050

The workers concluded that: "There was a marked relation between high proteolytic counts on tryptone-skim milk agar and poor keeping quality.

"A marked relation was found between high lipolytic counts on tributyrin medium and poor keeping quality. This relationship was less marked when nile-blue-sulphate medium was used."

The writer fails to see the relationship in any of the above tables.

Jacobsen found large numbers of lipolytic and proteolytic bacteria were present in certain of his samples of unsalted butter after holding at room temperature, but no definite correlation could be noted between the growth of these types of bacteria and the development of flavour defects (95).

No work of a convincing nature appears to have been reported to show that proteolytic or lipolytic counts are related to the keeping quality of butter. To show whether any such relation exists samples of butter should be prepared, divided, and preservative added to one part of each sample. If the difference between the deterioration in the normal portions and the preserved control portions—both portions being kept in identical conditions—could be correlated with the numbers of any type of organism, then one would be justified in assuming that deterioration was due to the type of organisms studied.

The Growth of Yeasts in Butter.

Because the acidity of media for the detection of yeasts and moulds has, in the earlier work, not been satisfactorily standardised, reliable data showing the effect of salt on the growth of yeasts in butter is not available.

It is proposed to show some data reported in the literature as yeast counts, but which it would be more correct to regard merely as counts of the acid-tolerant flora, including yeasts and indefinite numbers of acid-tolerant bacteria.

The following data is taken from a paper by Macy (86).

RELATION OF YEAST COUNTS TO SALT CONTENT OF BRINE.

Salt Content of Brine (per cent.).	Distribution of Yeast Counts in each Group.			
	10 or less.	11 to 50.	51 to 100.	101 or more.
Unsalted	28·1	14·0	16·7	41·2
0·4— 7·9	34·8	8·7	8·7	47·8
8·0— 8·9	24·4	17·8	26·6	31·2
9·0— 9·9	19·8	33·3	13·6	33·3
10·0—10·9	27·3	33·5	15·3	23·9
11·0—11·9	22·6	41·2	17·7	18·5
12·0—12·9	18·7	40·0	19·6	21·7
13·0—13·9	26·6	38·7	15·5	19·2
14·0—14·9	30·2	40·4	14·2	15·2
15·0—15·9	33·6	42·5	11·4	12·5
16·0—16·9	33·9	45·3	10·7	10·1
17·0—17·9	41·2	48·5	7·4	2·9
18·0—18·9	47·2	41·7	5·6	5·5
19·0—26·9	36·4	63·6	0·0	0·0

The data was obtained for "yeast counts" on 2,700 lots of butter of varying composition, age and quality, and made in many creameries. The samples were taken at random from 60 lb. tubs of butter as they were shipped to the market. The counts were made on whey-agar medium acidified with 1 cc. of 1% sterile tartaric acid solution at the time of plating.

The following data was reported by Macy (94). The samples were stored in very varied conditions.

THE EFFECT OF SALT ON THE CHANGE IN "YEAST" COUNT DURING STORAGE OF BUTTER.

Salt Content.	Total Samples.	Change of "Yeast" Count.		
		Increased.	No Change.	Decreased.
0·0	62	71·4	3·4	25·2
0·4—0·95	123	38·7	1·6	59·7
1·0—1·9	207	33·3	4·9	61·8
2·0—3·4	213	29·1	6·6	64·3

Spitzer & Parfitt presented the following data (59). It was obtained by examination of 183 samples of butter submitted for competition and held in cold store for approximately three months.

The effect of salt upon the per cent. of butters increasing in numbers of micro-organisms during storage.

Per cent. salt in brines	0–5	5.1–10	10.1–15	15.1–20
Yeast counts	40.000	48.62	21.42	5.26

From the above information it must be concluded that accurate data regarding the effect of conditions upon the various types of microbial growth in butter is lacking. However, sufficient data is available with regard to the effect of salt

to indicate the necessity of carefully controlling the salt content of butter. The growth of many species of organisms is inhibited when the concentration of salt in the butter serum is about 10.5% and the growth of most species is inhibited when the concentration is raised to 16%. With butter containing 16% moisture, the salt contents of the butter to give these concentrations of salt in the serum are 1.7% and 2.6% respectively.

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*Original paper not seen.

ERRATA.

Volume 17 No. 1, March, 1940.

Page 107, line 12, read "were" for "was."

Page 111, last paragraph, line 5, read "the" for "with."

Page 134, paragraph 2, line 3, insert "viable" between "of" and "organisms," and delete "capable of developing."

Soil Erosion.

Report of the Soil Conservation Committee on the incidence of soil erosion in the agricultural areas of Western Australia within the 12-25 *inch rainfall belt.*

The matter of soil conservation and the control of the ravages of soil erosion has received the attention of public authorities in many parts of the world.

In Australia soil erosion and conservation methods were considered by the Conference of the Commonwealth and State Ministers held in Adelaide, August 26th to 29th, 1936, when it was decided to request all State Governments in the Commonwealth to form Soil Erosion and Conservation Committees to co-ordinate the work in the Commonwealth. All State Governments have given effect to this decision and in New South Wales, in addition, a Soil Conservation Service has been formed.

The Western Australian committee was constituted as a Soil Erosion Committee by the Hon. Minister for Agriculture, Mr. F. J. S. Wise, on December 22nd, 1936. This committee was later enlarged and reorganised as a Soil Conservation Committee and now consists of the following Government officers: the Conservator of Forests, Mr. S. L. Kessell, chairman; the Surveyor-General, Mr. W. V. Fyfe; the Superintendent of Wheat Farming, Mr. I. Thomas; the Officer in Charge of Irrigation, Mr. A. R. C. Clifton; the Superintendent of Horticulture, Mr. H. R. Powell; the Superintendent of Dairying, Mr. G. K. Baron-Hay; a representative of the Agricultural Bank, Mr. C. P. Murray; the Plant Nutrition Officer, Dr. L. J. H. Teakle, secretary.

Reports of soil erosion have already been published by the New South Wales, Victorian* and South Australian† authorities and this report is designed to summarise the progress as a result of the work of the Soil Conservation Committee in Western Australia.

At its first meetings the committee considered the incidence of soil erosion problems throughout the whole State. Reports were obtained from field officers of Government departments in outlying districts to supplement the personal observations of members of the committee. As a result of this preliminary survey, it was decided to direct attention for the time being to the agricultural areas lying between the 12 and 25 inch isohyets. The absence of high mountain ranges in the extreme South-West, coupled with the fact that the important catchment areas are State forests, greatly minimizes any danger from widespread water erosion in this region.

In the drier pastoral areas which occupy a large proportion of the State, a few tracts of country are suffering severely from wind erosion following long periods of drought, but the State is fortunate in that the soils in pastoral areas for the most part are types not liable to extensive drift.

Following the decision to concentrate attention first on erosion problems in the wheat-farming and mixed-farming areas of the 12-25 inch rainfall belt, a printed form of questionnaire was distributed to some 664 farmers nominated by 55 road boards, and the balance of this report deals exclusively with this region.

The questionnaire was sent out in March, 1939, and the bulk of the replies was received over the winter months. Occasional replies are still coming in. Of the 664 questionnaires despatched, some 373 returns have been received. One

* Report of Committee appointed to investigate erosion in Victoria.
† Report of Soil Conservation Committee, South Australia, 1938.

road board, Gnowangerup, returned 12 out of the 12 questionnaires submitted, while one, Plantagenet, returned none. On an average, 6 to 9 returns were furnished from each road board where the farmers appeared to be interested in the question of soil erosion.

Many farmers submitted collateral evidence in the form of an attached statement (some 126 of these were received) and, in a number of instances, photos, plans and sketches were enclosed to illustrate answers.

A collateral problem resulting in land deterioration which appears to be causing more concern among farmers is that of soil salinity; some 33 drew special attention to the problem of soil salinity and many of these expressed concern at salt encroachment as affecting their own properties and neighbouring farms in their districts.

The Replies.

The replies have been carefully studied and an endeavour made to obtain farmers' views and assess the position from the farmers' viewpoints. It must be realised that expert inspection may have given a somewhat different picture but in the absence of that service, it is necessary to rely on the replies of farmers. There is no doubt that the replies are sufficiently accurate for a general survey with respect to soil erosion, as the majority of replies show that, generally, the farmers submitting returns had a very keen appreciation of this problem and its implications. There is no doubt that these farmers have accumulated accurate knowledge concerning the conditions leading to soil erosion as a result of observations on their own farms and are appreciative of the need for control; in fact, in many instances control measures, more or less successful, have been applied on their own initiative.

The replies indicate that it is generally conceded that soil erosion is due to faulty management and conservation will be achieved largely as a result of the proper adaptation of soil management, use of wind breaks and proper cultural and cropping methods under the prevailing conditions.

In order to obtain an intelligible picture of the incidence of water and wind erosion, the situation with respect to erosion, as reported by each farmer, has been graded into 5 classes:—

1. None obvious.
2. Very slight, less than 1 per cent. estimated damage.
3. Slight, 1 to 5 per cent. damage.
4. Moderate, 5 to 15 per cent. damage.
5. Severe, over 15 per cent. damage.

It is to be noted that very few reported a severe incidence of soil erosion.

These classes are not related to any published in the literature, but were adopted as a convenient means for interpretation in a general way of the replies received. They should be considered according to the definition and not according to any preconceived ideas from surveys in other places. In this connection attention may be drawn to the contrast with the situation in the United States of America where about 100,000,000 acres of once fertile land have been essentially ruined for practical cultivation by erosion and where the degree of erosion is indicated by similar terms but used in a different sense (in this case with respect to sheet erosion by water action). For instance, in the report on soil erosion in Iowa* the term *slight* refers to areas from which less than 25 per cent of the

* "Soil Erosion in Iowa." Special Report No. 2, April, 1936, of Soils subsection, Iowa Agricultural Experiment Station and Soil Conservation Service, U.S.D.A. co-operating.

surface soil has been removed, *moderate* to areas from which 25 to 50 per cent of the surface soil has been removed and *severe* to areas from which more than 75 per cent. of the surface soil has been removed and the subsoil has been carried away in many instances.

In Western Australia, while soil erosion has not yet reached serious proportions in the agricultural areas, it is of widespread occurrence and, in many instances, is on the increase. To avoid such serious consequences of faulty land management, it is necessary for farmers in this State to take immediate steps to organise their farming operations to prevent the progressive action of the forces of erosion and to effect reclamation of those areas already damaged.

The Incidence of Soil Erosion.

The replies indicate that soil erosion, due to wind and water action, is widespread throughout the agricultural areas. Generally the damage which has resulted is slight but the reports leave no doubt that soil erosion is on the increase in many instances.

Table 1 shows a grading of the replies according to the classes given above.

Table 1.

Incidence of Soil Erosion in Western Australia as indicated by the replies submitted by farmers to the questionnaire circulated by the Soil Conservation Committee.

Type of Erosion.		Severity of Soil Erosion.					
		None.	Very Slight.	Slight.	Moderate.	Severe.	Total.
Water ...	No. of Replies	116	107	116	28	6	373
	Per cent.	31·1	28·7	31·1	7·5	1·6	100·0
Wind ...	No. of Replies	119	90	83	66	15	373
	Per cent.	31.9	24.1	22.3	17.7	4.0	100.0

A survey of the replies to the question concerning the course of soil erosion is summarised in Table 2.

Table 2.

The course of Soil Erosion on farms in Western Australia.

Type of Erosion.		Course of Soil Erosion.				
		Improving.	Stationary.	Slight Increase.	Moderate to Rapid Increase.	Total.
Water ...	No. of Replies	2	69	131	46	248
	Per cent.	1	28	53	18	100
Wind ...	No. of Replies	2	108	95	37	242
	Per cent.	1	45	39	15	100

General Comments.

In the course of the replies, a number of important points were made by farmers and these are summarised as follows:—

1. *Water Erosion.*—Water erosion is essentially a problem of the hilly portions of the districts receiving over 15-inch annual rainfall, and generally shows within 5 to 15 years of clearing. In some instances it is reported that water erosion has appeared earlier and in other instances a longer period has elapsed before water erosion has become apparent. It is recognised as due primarily to improper farming methods and that improved farm management will minimise the damage, and, perhaps, result in improvement in the future. The value of a pasture period or a forage crop lightly grazed, in controlling soil erosion, is well recognised. The damage occurs chiefly on fallow or newly cultivated land after heavy summer or early winter rains. Wet winters also promote water erosion. All types of country are affected where the land is sloping or where there is run-off from catchment areas.

Once soil erosion commences, it increases rapidly for a number of years but often reaches a limit and thereafter remains stationary or improvement sets in. This may be due to changed methods of management on the affected areas.

There is some evidence of sheet erosion, but the damage is caused mainly by gully erosion. Gully erosion does not cause damage to extensive areas, but results in great inconvenience due to the cutting up of paddocks into irregular shaped areas unsuitable for the use of modern machinery. Many farmers regard the gutters as of some value for improving drainage conditions in the cultivated paddocks; there is no doubt that these gullies remove rapidly a considerable amount of excess water which accumulates during the winter months, but it seems likely that a similar benefit may be obtained without the inconvenience of irregular gutters cut haphazardly in the field if some attention to the control of run-off water were given at the outset.

Generally cultivation is the fore-runner of water erosion. A commencement is frequently made where wheeled vehicles are driven up slopes under cultivated conditions. Ploughing out corner headlands is a frequent origin of gully formation and working up and down long slops promotes run-off and losses of soil. Gullies very frequently commence at gates or along sheep pads where they run up and down slopes. Salt patches commonly form the source of a gully, or the commencement of an eroded area.

Control measures generally suggested involve improved farm management and pasture establishment. A number of farmers report having adopted a long rotation with particular attention to the pasture period where the rainfall is more suitable for mixed farming. More judicious cropping, contour working and the use of contour banks on long, steep slopes have been suggested as means of minimising, if not eliminating, the damage from water erosion. Burning of stubbles should not be followed as a general practice on account of the promotion of run-off. Farmers realise, of course, that heavy floods, particularly in the summer time, will always cause a certain amount of damage, but consider that the above control measures will minimise that damage.

Where gullies have been established the use of stones, boughs, straw and rubbish to form dams assists in reclamation, but frequently little benefit is reported as new breaks occur in subsequent wet periods. This points, of course, to the need for the judicious use of contour banks in such instances. Fallows should be left rough where liable to erosion and corners should not be ploughed out if on slopes which may accumulate water.

One farmer illustrated by means of a diagram the use of small banks to prevent the run of water along sheep pads. Some farmers advise leaving the valleys uncleared in order to prevent the formation of gullies in these valleys.

Regarding implements, there seems to be a diversity of opinion. A number of people feel that the mouldboard plough leaves the surface too smooth and recommend the scarifier as a more suitable implement to leave a desirable, rough surface where water erosion is liable. Others hold different views.

2. *Wind Erosion.*—Farmers who are experiencing wind erosion are practically unanimous in pointing to the run of dry seasons as the underlying cause for the increased incidence of this problem in the last four years. They also feel that, with the advent of better rainfall years, the manifestations will largely disappear.

Soil types most severely affected by wind erosion are:—

(a) Loose sandy types such as pear (*Xylomelum angustifolium*) and sandy mallee country.
(b) Snuffy morrel country.
(c) Red sandy loams on sedimentary formations in the Yuna and Yandanooka areas.

Occasionally wind erosion occurs on heavy clay flats where drought has led to the breaking down of the soil structure.

It is reported that damage observed is chiefly of the nature of drifts interfering with fences and other improvements. There has apparently been little loss in yield or productivity, except in a few cases.

It is generally conceded that the advent of wind erosion has been increased by excessive clearing, over-stocking, depredations of grasshoppers and rabbits, over-cultivation to produce a fine surface mulch and like causes. On many farms large areas have been cleared on a face and even the timber along the roads has been destroyed in order to allow crops to grow right up to boundaries. Stubble burning has also accelerated wind erosion. It is commonly observed that wind erosion is most apparent during the fallow period, particularly if the fallow is worked to a fine tilth.

In discussing the control measures, farmers have pointed to the need for timber belts and have recommended that, as far as possible, 2-chain roads should be surveyed in agricultural areas and steps taken to preserve the timber along these roads. Many farmers are looking for means which will render the establishment of timber belts possible at low cost. One farmer claims that he has doubled the growth of grass on one area as a result of establishing a strip of 1,000 pines and is naturally enthusiastic about this means of protecting the soil

Loose, sandy types of soil which will not produce consistent crops should not be brought under cultivation and, on all types liable to wind erosion, some vegetation cover should be maintained throughout the year to limit the action of the wind. Some farmers mention the value of cropping to oats or rye and light stocking to protect the surface. At Irwin, 100 per cent. control of a severe wind erosion problem has been obtained as a result of the use of blue lupins combined with judicious stock management. Subterranean clover has proved beneficial in some of the wetter areas as at Glentromie.

There is no consistency in the opinions regarding the effect of stock, particularly sheep, on wind erosion. Some people have found that pulverising the soil as a result of stocking may accelerate erosion, while others feel that the compacting action is beneficial. Rabbits, in destroying the vegetation cover, are a menace.

Wind erosion usually becomes evident in the first few years after clearing and cultivation, and is particularly evident during periods of drought and on land which is over-stocked.

The replies indicate a general confidence that control would be effected when better seasons occurred and that an improved adjustment of farm management would be effective in limiting wind erosion to a negligible extent.

3. *Soil Salinity.*—The numerous references to salt encroachment contained in the replies render it desirable to draw attention to the fact that, apart from damage resulting from the encrusted patches associated with soil salinity manifestations, there is accelerated wind and water erosion on account of the lack of vegetation. These bare, saline patches often form the heads of gullies and washes, and where a powdery surface forms, as is very frequent, this is blown away by the action of the wind and several inches of top soil have been removed in many areas affected by salt encroachment.

4. *General.*—In discussing the matter of soil erosion more generally, a number of farmers have expressed a desire for legislation to compel proper attention to the problem of soil erosion. The matter of conserving belts of timber, planting of wind breaks, conservation of timber along roads, and the surveying of wider roads where timber could be specially protected, have been mentioned.

One farmer suggested that an inspector should be appointed with power to quarantine areas liable to soil erosion.

Only a few farmers drew attention to the economics of soil erosion control measures or suggested the need for Government assistance. Some pointed out that low prices and poor seasons had limited the farmer's ability to undertake such conservation work, but there appeared to be a very general appreciation on the part of farmers, of the need for soil conservation and a great many had already adopted some control measures.

There seems to be need for technical advice to assist the farmers in using their efforts at soil erosion control to the best advantage. From the numerous offers of assistance to Government officers working on soil erosion control, it seems that farmers generally are now ready to undertake appropriate measures for soil conservation before the problem reaches a degree of even moderate severity.

Future Programme of the Soil Conservation Committee.

While it is recognised that soil erosion is widespread in the agricultural areas of Western Australia, in general damage it has not reached serious proportions but it is increasing in many cases.

As conservation is much to be preferred to reclamation, an active educational programme is to be organised to assist in the development of conservation methods, as well as demonstration of control methods. To this end it is planned to arrange conferences of Government officers at convenient centres in order to consider thoroughly the matter of soil erosion and its control under local conditions, and to lay down principles as a basis for uniformity of advice and action. These officers will undertake advisory work and practical demonstrations so that farmers may be acquainted with the most effective and efficient means of combating soil erosion on their own farms and of organising their farming practice to arrest the damage and promote reclamation.

The Thanks of the Soil Conservation Committee.

The Soil Conservation Committee expresses its appreciation of the work of farmers who have supplied information in reply to the questionnaire. It was evident that no effort was spared to give a reliable and considered report on erosion as it affected their individual farms and surrounding districts, and all are asked to accept the committee's thanks.

S. L. KESSELL,
Chairman.

L. J. H. TEAKLE,
Secretary.
Soil Conservation Committee.

Subsoiling with Explosives.

V. Cahill.
Horticultural Instructor.

In areas where agricultural soils are underlaid with layers of stiff clay or by hard-pans, considerable benefit is often obtained by subsoiling with explosives. Under such conditions subsoiling allows of adequate drainage during the winter months and so prevents waterlogged conditions associated with shallow-rooting of plants. The deeper rooting consequent on the opening of the subsoil permits roots of plants to develop over a greater area from which plant nutrients may be obtained.

This loosening of the subsoil is particularly important where orchards have been established on soils below which compact clays or hard-pans of various types are found if for no other reason than to enable trees to obtain sufficient supplies of water, during the summer months, for growth and fruiting. The effects on trees of winter waterlogging of the roots are only too well known for orchardists not to appreciate the benefit to be derived from improved drainage on such subsoils.

In connection with the loosening of hard subsoils, Mr. A. Despeissis (1) writes: "Good results have been obtained by using explosives to crack the subsoil where it is intended to set trees or by blasting the ground in the winter in the proximity of trees already planted."

Further, Mr. H. C. Coggins (2) in a paper dealing with subsoiling in various parts of New South Wales on a number of soils, states that he finds subsoiling with explosives is by far the cheapest and best method, even for breaking up hard-pans which are created by constant ploughing at the one depth. This applies also to old jinker tracks and roads through orchards.

In many orchards it will be found that practically all of the rooting system is very close to the surface and this is very liable to be damaged by deep ploughing. The use of explosives enables subsoiling to be done without the removal of the top soil and it causes a series of fissures in the subsoil extending in all directions. The holes in which the charges are placed are spaced so that the resulting fissures from the separate charges meet, and a complete network is formed.

By using explosives, one man equipped with a few tools, namely, a two inch bull nosed auger, a tamping rod, and a pointed crowbar, can obtain an effect which could only be procured by considerable expenditure by any other method.

Trials with Explosives.

In response to several requests for information regarding the use of explosives, interest was taken in this type of work carried out in the orchard of Mr. C. H. Hunter at Clackline, in 1932. The operations were spread over two acres of orchard, consisting of citrus, stone fruit and pear trees. The subsoil in this orchard is of a stiff clay nature and the work was done during the season March-April.

Single charges consisting of four-ounce plugs of "monobel" explosive were placed in holes three feet deep in line with the trees, six feet apart. It was estimated that the subsoil was disturbed to a radius of seven to nine feet by the resultant explosions. The results of this treatment have been very satisfactory as the trees have made excellent growth since that time.

In 1936, during the late summer, another trial was made at Mr. L Bassola's orchard at Chidlow, where an area consisting of four rows of four-year-old apple trees was treated similarly. These trees are now growing more vigorously than the other trees on untreated portions of the orchard.

In 1935 Mr. E. G. Bullen, of Wooroloo, carried out some similar work, using dynamite, in connection with pear trees which had previously made poor leader growth. This year the trees are making good terminal growth and are in a much more vigorous condition, also carrying a good crop of fruit.

Method.

The amount of explosive to be used in the holes will vary somewhat with the type of subsoil. For this reason a test hole should be put down about three feet deep and a four ounce plug of explosive fitted with safety fuse used. A slow acting explosive such as "monobel" has given the best results in the trials carried out.

Safety fuse as used for blasting purposes burns and does not explode. For detonation of the explosive it is advisable to use detonators of type No. 6.

Effect of Test.

To determine the effect of the test an excavation should be made a few feet away from where the test charge was exploded. Fractures observed will enable the operator to form a very good idea of the nature of the result. A poor fracture of the subsoil as seen in the excavation will indicate that more explosive is needed or vice versa.

When the size of the charge to be used has been determined, holes should be bored 2ft. 6in. to 3ft. deep and spaced six to ten feet apart depending on the nature and strength of the subsoil or hardpan as indicated by the test. Where the subsoil consists of a stiff, impervious clay, best results are obtained when the ground is dry as when wet such subsoils are liable to pug and will not shatter.

Summary.

1. Trials show that when hardpans, etc., have been treated by the use of explosives, fruit trees make more vigorous growth.

2. Details are given of the method used.

3. Subsoiling by explosives is warranted only on soils where an impervious layer of definite thickness exists.

The advantages of subsoiling by explosives are as follows:—

1. Conservation of moisture.
2. Better drainage.
3. Better aeration.
4. Roots of the plants are able to penetrate deeper.

The amount of "monobel" explosive used per acre in the trials cited above was one case consisting of 200 cartridges, costing £2 2s. 0d.

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Experiments on Copper Deficient Land at Dandaragan, Western Australia.

By L. J. H. Teakle,[1] A. G. Turton,[2] and G. L. Throssell.[1]

INTRODUCTION.

The settlers in the Dandaragan area have long known that, under ordinary farming practice, certain classes of soil, apparently normal in general properties, are unsuitable for the growth of cereal crops and, after clearing, have a value for grazing purposes only. Some settlers have explained that the reason for these crop failures is an excessive richness in the soils which "burns" the growing crop and, in consequence of the unsatisfactory returns, development of these types of soil has not been extensive. However, in spite of the advice of settlers with a wide experience of local conditions, Mr. Brown of "Bidgerabbie," Location 1466, Dandaragan, cleared some 150 acres of blue gum flat country on his property in 1931 with a view to growing cereal crops as an adjunct to stock raising. The class of land closely resembled that associated with earlier crop failures in other parts of the district and neighbours predicted disappointing returns.

Barley was the first cereal crop on the area represented by the plots described in this paper and was scratched in on the newly cleared land in 1932. A good growth of straw was produced, but the heads failed to fill satisfactorily with grain over portions of the crop. After four years of pasture the paddock was fallowed in 1937 and sown in the middle of May, 1938, under excellent conditions, with oats, wheat and rye. Over considerable portions of the area the oats and wheat proved a complete failure and satisfactory growth was obtained only on the marginal portions of the field in proximity to the sandplain country to the east. Even here the grain was badly shrivelled.

A report of this crop failure was communicated to the Hon. Mr. P. D. Ferguson, who wrote to the Department of Agriculture on November 22nd, 1938, requesting that an examination be made to ascertain the reason for the blighting of the crops under conditions under which excellent returns could reasonably be expected.

[1] Department of Agriculture. [2] Chemist, Government Chemical Laboratory.

A field inspection was made by the senior author on November 26th just prior to harvesting and full details obtained from Mr. Brown. In describing the growth of Burt's Early oats during the season he explained that apparently the germination was quite satisfactory and the crop grew normally for about four weeks. In the following weeks, however, it became pale in colour and drooping in habit. Closer examination showed that the tips of the leaves and the edges of the leaf blades had turned a pale yellow. With the advance of time the tips coiled to give a stringy appearance with frayed ends. The leaves and stems lacked sufficient strength for normal erect growth, and the rooting system was very poor. As the season progressed most of the plants died out and the area was covered mainly by weeds such as flat weed (*Hypochoeris glabra*), drake (*Lolium temulentum*) and a number of other species, including *Cotula australis*. Where the crop had made better growth in the more marginal areas, the yield was low and the grain small or shrivelled.

In the case of rye the growth generally was much better than with wheat or oats, but, in many instances, the top portion of the ear had failed to fill, and grain occurred only in the bottom part. In extreme cases no grain at all had formed in the rye ears.

Throughout the area a number of large bushes of wild radish (*Raphanus raphanistrum*) were observed; these had made vigorous early growth but with maturation were failing to flower normally. The buds and flowers were small and the seed pods, in most instances, had failed to grow or set seed, giving a blighted appearance. Some of the leaves showed a yellow chlorosis between the veins and only a pale green coloration on the veins themselves.

The symptoms described by Mr. Brown very closely paralleled those published by Riceman and Donald (1938) describing their experience with crops grown on copper deficient soils in the south-east of South Australia and the circumstances indicated a clear case of copper deficiency. In view of this, and in order to obtain information which would lead to a practical solution of the problem, arrangements were made for the carrying out of a comprehensive fertiliser experiment to be commenced in May, 1939. It was hoped that the results would be of value on Bidgerabbie and also to other settlers farming similar land.

The Dandaragan area lies at the northern end of the jarrah belt of Western Australia and botanical examination shows the principal vegetation associations to resemble closely those of the Perth area. The rainfall is generous and averages nearly 27 inches per annum distributed as shown in Table 1.

Table 1.

RAINFALL RECORDS FOR DANDARAGAN IN POINTS.

(100 points = 1 inch.)

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1939	208	239	3	34	402	635	812	574	37	121	69	12	3,146
Average 1898–1938....	27	43	79	118	361	534	532	411	288	182	45	41	2,661

Geologically, the Dandaragan district is typically an exposure of Cretaceous sandstones, chalks and greensands similar to those at Gingin (Hosking and Greaves (1936)). The soils are generally similar to the Gingin types but a larger proportion of the heavier textured groups occur. As at Gingin, lambs and foals depastured solely on Dandaragan country become affected by enzootic ataxia or "rickets" which Bennetts and Chapman (1937) and Bennetts (1937) have shown to be a copper deficiency disease. This disease may be controlled by the administration of copper drenches or licks, or by topdressing pastures and crops with fer-

tilisers containing copper. On account of the incidence of enzootic ataxia, Mr. Inglis, of Yathroo Station, which joins Bidgerabbie, used fertilisers containing copper in 1938 and reported improved crop growth. This evidence strongly supported the diagnosis of acute copper deficiency as the cause of the crop failure under investigation.

PHYSIOGRAPHY AND SOILS.

The area concerned in the crop failure consists of an extensive flat surrounded by sandy rises. Soils related to the Koorian sand and Whakea sand of the Gingin district predominate on the western side, and on the eastern side the land rises to the gravelly sandplain typical of the Jurassic plain which extends to the north. There is little doubt that these flats represent an old lake bed which has been dry in modern times. With the receding of the waters there developed a cover of blue gum or flood gum (*Eucalyptus rudis*) with a sprinkling of marri (*E. calophylla*) along portions of the marginal areas. Ironstone gravel occurs in the marginal areas adjacent to the Jurassic sandplain and it is on these marginal areas that most satisfactory cereal crops are obtained. The most complete failure is in the central portion of the flat. Here growth to maturity occurs only on small patches which are apparently slightly raised above the general level. Throughout this central portion fragments of opaline casuarina stone* occur on the surface and casuarina stone appears to underlie the formation at a depth of 2 to 3 feet or more.

The colour of the soil is generally grey or grey brown, but browner patches occur in portions, particularly where the elevation is slightly above the general level.

A peculiar feature of the soils is their light, powdery nature. Their apparent specific gravity is only about two-thirds of that expected of mineral soils of similar texture. The most deficient soil types appear to be those which are lighest and most powdery in structure.

The characters of representative profiles are indicated by the following details:

Site 1: A grey soil type where oats were a complete failure.

0-3 ins. brownish grey loamy silt with opaline fragments.
3-12 ins. light grey loamy silt with harder particles.
12-22 ins. light grey to olive silty loam with harder fragments.
22-30 ins. olive clay to decomposing casuarina stone.

Site 2: Marginal area where York gum (*Eucalyptus foecunda* var. *loxophleba*) and marri were intermixed with the flood gum under virgin conditions. Dundee wheat had made fair vegetative growth but the grain was shrivelled.

0-3 ins. grey brown loamy sand.
3-9 ins. brown loamy sand.
9-21 ins. light fawnish brown light sandy loam with some fragments of casuarina stone at 24 inches.

Site 3: Complete failure of wheat and heads of rye almost invariably empty, regrowth occurring from the bottoms of the plants.

0-3 ins. grey brown silty loamy sand with opaline fragments.
3-15 ins. light brown loamy silt.
15-36 ins. khaki brown heavy sandy loam with odd opaline fragments. Cementy, sandy layer at 36 inches.

*Casuarina stone is a more or less consolidated diatomaceous earth.

Site 4: Oats a complete failure.

0-3 ins. brownish grey silty loamy sand.
3-7 ins. somewhat more compacted.
7-15 ins. pale bluish grey gritty silty sandy loam with opaline fragments.
15-24 ins. olive sandy clay loam with casuarina stone at 27 inches.

These soil samples have been examined for apparent specific gravity, salt, reaction, replaceable bases, phosphate, potash and copper. The results are given in Table 2.

TABLE 2.

PROPERTIES OF SOIL SAMPLES FROM THE AREA ON MR. J. A. V. BROWN'S PROPERTY, BIDGERABBIE, WHERE CROP FAILURES HAVE BEEN OVERCOME BY MEANS OF THE USE OF BLUESTONE AS A FERTILISER.

Site.	Serial No.	Depth.	Nitrogen	P_2O_5.	pH.	Salt.	Apparent* gravity.	Replaceable cations.				
								m. eq. per 100 gm. soil.	Per cent. of total cations other than hydrogen.			
									Ca.	Mg.	K.	Na.
		inches.	%	%		%						
1	2628	0—3	·200	·069	5·31	·06	1·05	11·75	38	45	7	10
	2629	3–12	·055	·032	5·31	·02	1·09	7·29	20	65	5	10
	2630	12–22	....	....	6·20	·02	1·24	...	...	...	..	
	2631	22–30	....	....	7·18	·02	1·03	...			..	
	2632	0– 3	·102	·045	6·09	·01	1·46	6·78	75	19	6	Tr.
	2633	3– 9	·063	·044	6·07	·01	1·50	5·00	76	17	7	*nil*
	2634	9–21	....	....	5·01	·01	1·35	....	....	.	.	
3	2635	0– 3	·140	·099	5·60	·02	1·06	8·21	67	23	10	Tr
	2636	3–15	·076	·093	5·45	·01	1·12	6·89	55	33	11	1
	2637	15–36	....	....	4·94	·04	1·24	....	....	....	....	....
4	2638	0– 3	·284	·160	5·37	·07	·90	12·28	48	37	10	5
	2639	3– 7	·161	·136	5·45	·03	·98	9·59	31	54	6	9
	2640	7–15	....	.. .	5·96	·04	1·11	....	....	....	....	
	2641	15–24	....	....	7·41	·05	·99			.	....	.

* Apparent specific gravity determined by weighing a standard volume of air dry soil after sieving through a number 10 sieve. The result is expressed as a multiple of the weight of the same volume of water. Apparent specific gravity normally ranges from 1·2 for clays to 1·7 for sands. Ordinary soils of this texture would be expected to have an apparent specific gravity of about 1·5.

Copper contents as determined by the dithizone method was of the order of magnitude of 1–2 p.p.m on the dry soil basis.

The copper estimations showed that the copper content was of the order of magnitude of 1 to 2 parts per million in the surface soil of each site. Thus, the site representing country on which wheat was not a complete failure appeared to have practically the same copper content as where cereals failed completely. Chemical examination failed to detect a significant difference.

The chemical analyses show the soils to be quite normal for this rainfall belt, that is, they are typical of the zone of podsolised or leached soils, Teakle (1938). The reaction is acidic and the replaceable cations other than hydrogen are principally calcium and magnesium. The phosphate status is considerably better than for most Western Australian soils and, in this respect resembles some of the better soil types at Gingin. Potash may be regarded as moderate.

FERTILISER EXPERIMENTS.

In order to ascertain the response of crops grown on this class of country to minor elements, particularly copper, an experiment was designed with the following objects:—

(a) To determine whether the addition of copper to the ordinary fertiliser would affect the growth of oats.

(b) If so, to indicate how much copper must be applied in the form of bluestone.

(c) To ascertain whether growth of cereal crops would be further improved by the inclusion of other minor elements.

A 5 x 5 randomised block layout was adopted to obtain accurate yield data to answer these questions and the following treatments were used*:—

A. Control, 1 cwt. of superphosphate per acre.

B. 1 cwt. of superphosphate mixed with 5 lbs. of bluestone per acre.

C. 1 cwt. of superphosphate mixed with 15 lbs. of bluestone per acre.

D. 1 cwt. of superphosphate mixed with 30 lbs. of bluestone per acre.

E. 1 cwt. of superphosphate mixed with 15 lbs. of bluestone, 15 lbs. manganese sulphate, 20 lbs. magnesium sulphate, 20 lbs. ferrous sulphate, 5 lbs. zinc sulphate, 5 lbs. borax per acre.

The experiment was conducted on a portion of the flat on which the cereal crop had failed completely in 1938. The stubble was burnt where small patches had made some early growth and the land disc cultivated in January, 1939. After being spring-tyned in early May to kill weeds and prepare a seed bed, Burt's Early oats at the rate of 50 lbs. per acre and the appropriate fertilisers were sown on May 13th, 1939.

THE GROWTH OF THE OATS.

Observations made during the growing season showed that germination was generally good over all of the plots. Little difference was observed between any of the treatments during the first four weeks but by the middle of June, on the control plots, the plants were beginning to show a distinct yellowness and were obviously unthrifty. Growth on the control plots had practically ceased by the beginning of August and the plants were becoming progressively more yellow, showing typical copper deficiency symptoms. Some plants were already beginning to die.

Figure 1 shows a comparison of the growth with and without copper on July 26th, 1939.

Early in September, on the control plots, most of the oats had died and only scattered survivors occurred over the plots. These showed typical symptoms of copper deficiency as described by Riceman and Donald (1938) and, in general, made practically no headway subsequently.

Figure 2 shows a general view of a control plot between two plots which had received bluestone in the fertiliser mixture. These plots are gratifyingly uniform in their growth and show a remarkably consistent response to the copper treatment. Figures 3 and 4 are close-ups of typical oat plants from the plots and show in some detail the characteristic copper deficiency symptoms on plants from the control plots.

By contrast, the other plots, which all received copper in the form of bluestone, continued to progress throughout the growing season and little difference, as a result of the various treatments which included copper in the mixture, could be observed at any period. During the first part of September the oat plants on the plots receiving only 5 lbs. of bluestone per acre certainly showed more evidence of withering of the tips of the leaves, but recovery was practically complete by the end of

*The fertilisers for these experiments were kindly supplied by Cuming Smith and Mt. Lyell Farmers' Fertilisers, Lt .

September when all copper treated plots were heading out nicely. At harvest time (November 6th and 7th, 1939), all of the copper treated plots carried an excellent growth of oats. It is true that over the length of these plots the growth showed

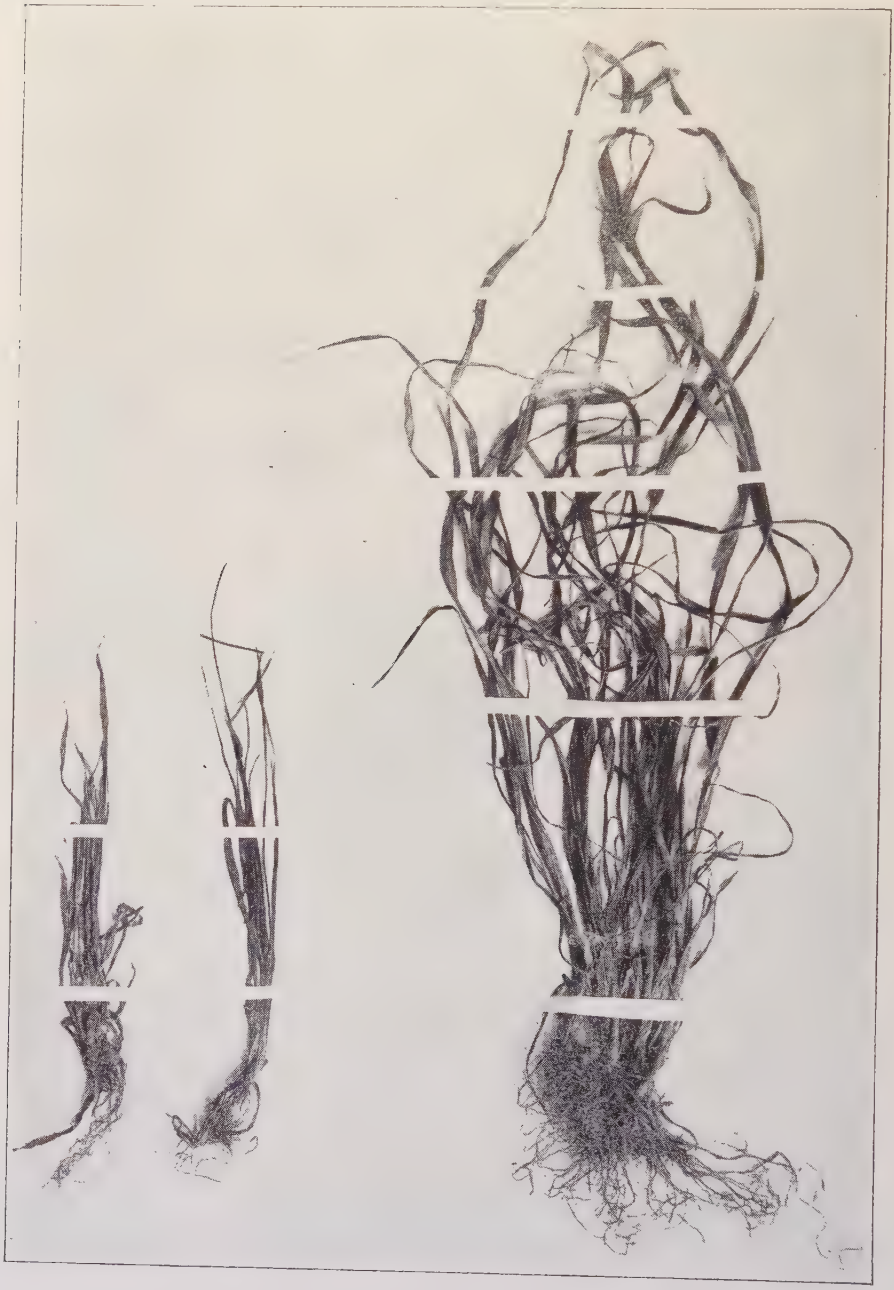

Figure 1.
Shows nature of growth of oats on plots receiving superphosphate only (left) and superphosphate plus 5 lbs. bluestone per acre. Harvested July 26th, 1939.

Figure 2.

General view of plots taken September 5th, 1939, showing the control plot (19) in contrast with plots receiving bluestone at the rate of 15 lbs. per acre in combination with manganese, zinc, boron, iron and magnesium (left) and bluestone at the rate of 5 lbs. per acre (right). The growth apparent on the control plot (19) is principally drake (*Laluim temulentum*).

some lack of uniformity, probably due in part to the fact that the land had not been fallowed and some growth of oats had occurred in patches during the previous season, but no sign of crop failure was observed where copper had been applied.

Figure 5 gives a close-up of typical oat plants from copper-treated plots at harvest time (November 7th, 1939), in contrast with selected surviving plants, which were scattered over the control plots and had reached various stages of maturity. These show typical copper deficiency symptoms.

As a satisfactory machine was not available to harvest the plots, estimates of yields were obtained by means of 36in. x 35in. quadrats taken at eight sites selected at random in each plot. By this means no loss of material was incurred and the yields reported represent the total material produced.

The yields exceeded all expectations and comparison of the returns from the various plots showed that there was no significant difference due to any of the variations in the copper treatment. The controls (receiving no copper) were practically a complete failure and no yield estimates were obtainable from any part of the five replications.

The hay and grain yields estimated from the quadrats are given in Table 3.

Table 3.

HAY AND GRAIN YIELDS FROM THE VARIOUS TREATMENTS ON THE DANDARAGAN PLOTS. ESTIMATED FROM THE WEIGHTS OBTAINED FROM QUADRATS 36IN. x 35IN.

	Hay Yield per acre.	Grain Yield per acre.
	tons. cwts.	bus.
Superphosphate only	*Nil*	*Nil*
Superphosphate plus 5 lbs. of bluestone per acre ...	3 14	45·5
Superphosphate plus 15 lbs. of bluestone per acre ...	3 14	45·6
Superphosphate plus 30 lbs. of bluestone per acre ...	3 14	50·7
Superphosphate plus complex mixture	3 16	49·2

Figure 3.
Typical oat plants harvested on September 5th, 1939, to show the growth:—
(a) with bluestone (Specimens 1 and 2) and
(b) without bluestone (Specimen group 3).
(The scale is 15 inches long.)

The grain from all plots was rather thin but gave a bushel weight of 38.5 lbs. determined by the chondrometer.

Statistical examination of the harvest returns shows that the differences between the hay and grain yields on copper treated plots are too small to be significant and are most probably the result of chance variations in the fertility levels of the soil on different parts of the experimental area. It is of very considerable interest that no improvement in yield resulted from the use of bluestone in excess of 5 lbs. per acre or when mixed with other elements.

Figure 4.

Oat plant harvested on September 5th, 1939, from the control plot to show the typical copper deficiency symptoms exhibited on the Dandaragan plots. Note the stringy tipping of the leaves and the tendency for the leaves to die back from the tips and along the edges. Rooting system is very poor.

The weeds were fairly prevalent throughout the plots and had practically taken possession on the controls where the oats had died. Drake was the principal weed and had made vigorous growth throughout. Other weeds included chick weed (*Stellaria media*) and a small annual known as *Cotula australis*. Yathroo oat occurred as a weed throughout the plots. Apparently these weeds are all more or less tolerant of copper deficiency conditions.

EXAMINATION OF THE OATS.

In order to obtain information concerning the chemical composition of the oats and any anatomical differences which may be associated with the various treatments, samples were taken on September 5th, 1939, for chemical analysis and microscopical examination. At this time, the surviving oats from the control plots

were 6 to 8 inches high and had only produced four or five leaves. They had not yet begun to run up preparatory to ear formation (Figures 3 and 4). On the other hand, on the copper treated plots the cats were 24 to 30 inches high, had produced five or six leaves and were beginning to run up into ear. (Figure 3.)

Figure 5.

Mature oat plants at harvest (about 4½ to 5 feet tall) from plots receiving copper (left), in contrast with selected surviving plants from control plots (right) which show typical copper deficiency symptoms.

It is evident that, in the absence of copper, development had been arrested and these plants were physiologically and anatomically younger than those which had received copper. For that reason alone it would be expected that chemical and anatomical differences would be observed on examination. Differences may also be due to deficiency of copper giving rise to abnormalities. Examination of the plant material from each of the 25 plots for chemical properties in the Government Chemical Laboratory gave the results summarised in Table 4.

Table 4.

COMPOSITION OF OAT PLANTS FROM THE BIDGERABBIE PLOTS HARVESTED ON 5th SEPTEMBER, 1939.

(Results expressed on the basis of oven-dry material.)

Treatment.	Total Ash.	Silica-free Ash.	Total Nitrogen.	Copper (Cu).
	%	%	%	p.p.m.
Control—Superphosphate	13·03	8·50	2·83	1·9
Superphosphate plus bluestone, 5 lbs. per acre	9·06	5·76	1·29	3·4
Superphosphate plus bluestone, 15 lbs. per acre	10·59	6·62	1·59	3·7
Superphosphate plus bluestone, 30 lbs. per acre	9·07	5·64	1·25	2·9
Superphosphate plus mixture containing copper, manganese, zinc, boron, iron, and magnesium	8·66	5·20	1·08	1·9

Statistical examination of the results show that—

(a) the total ash content was higher in the controls;

(b) no significant differences occurred in the copper contents of the plant material under the several treatments;

(c) the percentage of nitrogen was greater in the controls than in any other treatment but there were no significant differences in nitrogen content of the plant material from the various copper treatments.

Work reported by Piper (in press) in Adelaide supports the evidence obtained in these experiments concerning the effect of copper treatment on the copper content of oats. It seems unfortunate that oats show such a small copper content and do not exhibit a more consistent response in copper content when treated with copper containing fertilisers even on highly copper deficient soils. Of course, the total absorption of copper from the soil under the copper treatments would be very greatly in excess of that from the controls on account of the increased amount of growth which has been made. Yield figures which would enable the difference in total amount of copper absorbed to be estimated were not obtained. Furthermore, although statistical analysis indicates the apparent differences in copper content of the oats under the various treatments may not be significant, it seems that a grazing animal would have a better chance of obtaining more adequate copper requirements from crops receiving the copper fertiliser.

Observations by Miss Ford of the University Department of Botany reported in the Appendix, show marked microscopic differences between the control plants and those receiving copper when sampled on September 5th, 1939. Of course, some of these differences may be due to the arrested stage of development in the case of the plants from the control plots, but it is most likely that certain of these features are characteristic abnormalities exhibited under copper deficient conditions. It is hoped, however, that extension of such anatomical studies may lead to further information of value in connection with an understanding of the facts and functions of minor elements.

GENERAL OBSERVATIONS.

The early results of this work led Mr. Brown to use bluestone as a fertiliser fairly generally during 1939 on portions of his farm, and particularly in the home garden. The home garden is on a type of soil rather closely resembling the orange coloured Koorian sand of Gingin. Bluestone treatment has effected marked recovery of fig trees affected with mottle leaf. Maize is producing long, well filled cobs which are in marked contrast to those of previous years when only odd grains set. Tomatoes are bearing very much better than previously, apparently due to the use of bluestone.

However, strip experiments to observe the effect of bluestone on the growth of wheat on Koorian sand near the homestead failed to give any consistent results. Apparently, the Koorian sand is far less deficient in available copper supplies than the blue gum flat soils, but it seems likely from the responses of the maize, tomatoes and figs, that, with further cropping, copper deficiency with respect to cereals may manifest itself.

FUTURE EXPERIMENTS.

These plots are to be carried on for a number of years; in 1940 they will be sown to subterranean clover and wimmera rye grass; in 1941 they will again be sown to oats and half of each plot will receive the appropriate minor element treatment while the other half will receive superphosphate only to ascertain the residual value of the copper treatment. This rotation will be repeated for at least another two years.

In addition a further experiment is being laid down adjacent to the one just described, in order to ascertain the effect of smaller amounts of bluestone, namely 1, 2½ and 5 lbs. per acre. Further, the value of copper from oxidised copper ore obtained from Ravensthorpe will be determined as this source of copper is available at about one quarter the cost of the refined bluestone. Pyrites slag from Messrs. Cuming Smith & Mt. Lyell Farmers Fertilisers Ltd. residues, which contains between 1 and 2 per cent. copper, will also be tried.

Similar experiments have already been arranged on Mr. C. J. Roberts' property, "Kayanaba" and V. G. Rennie's property, Gingin.

A simple observational experiment will be conducted on "Yowerdabbie," Dandaragan, on soils of the Whakea sand and Koorian sand types.

CONCLUSIONS.

From these results it may be concluded that the crop failure under investigation was due to copper deficiency and excellent crops may be produced on the soils in question if copper is applied as a fertiliser. Five pounds of bluestone per acre mixed with superphosphate gave yields equal to any other treatment and no advantage was gained under these conditions from heavier applications. Less may suffice.

Analysis of the soils is not a satisfactory guide to copper deficiency. Observation of the symptoms exhibited by an indicator crop such as oats, or maize, followed by field trials, is the surest method of detecting such soil deficiencies.

It is not to be expected that such remarkable responses to the use of bluestone will be obtained generally on soils which are characterised by unsatisfactory crop growth. In fact, many experiments prove that such is not the case. However, there are patches of country, in the aggregate amounting to many thousands of acres and favourably located in the present agricultural areas, on which unsatisfactory returns are being obtained both from stock and crops as a result of copper deficiency. When these areas have been determined by means of field experimentation the efficiency of agriculture on these particular areas will be considerably

improved by the use of fertilisers containing copper. Farmers are advised to experiment before undertaking extensive fertiliser dressings with bluestone and similar amendments, as not only are these costly, but on some soils they have been known to bring about depressions in yields, even when used in such small quantities as 15 lbs. per acre. District agricultural advisers will give advice on the use of these special fertilisers and will assist farmers in planning simple experiments on their farms to determine the value of minor elements as adjuncts to the ordinary fertilisers.

ACKNOWLEDGMENTS.

Appreciation and thanks are tendered to Cuming Smith & Mt. Lyell Farmers' Fertilisers, Ltd., for the donation of the mixed fertilisers used in these experiments.

Grateful acknowledgment is made to officers of the Forests Department for the statistical examination of the results from the field and laboratory work, and to Mr. B. L. Southern, of the Government Chemical Laboratory, for assistance in the chemical work.

Special thanks are due to Mr. Brown who undertook the cultural operations involved and erected the necessary fencing.

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Appendix.

Anatomical Investigations of Oats (Burt's Early) obtained from Experimental Plots on Copper Deficient Land at Dandaragan.

by

J. M. Ford.*

The investigation was undertaken to discover if oats, grown on the control plots and showing typical copper deficiency symptoms on Mr. J. A. V. Brown's property, "Bidgerabbie," differed anatomically from those grown on the plots receiving copper treatment in addition to the usual superphosphate.

At the time of collection, September 5th, 1939—12 weeks after planting—the plants were very different in external appearance in comparison with the healthy plants receiving copper; those suffering a deficiency of copper were stunted in growth and possessed a poorly developed root system. A noticeable feature was the restricted elongation of the internodes which resulted in the nodes (or knots of the stem) being close together at the base of the plant. Other symptoms have been mentioned and are illustrated in figures 3 and 4.

*Hackett Scholar in Botany, 1939, University of Western Australia.

Results of Anatomical Investigation.

In order to determine the structural differences between the leaves and stems of affected and copper treated plants, sections of representative material were cut and examined by means of the microscope. Figure A shows transverse sections of the

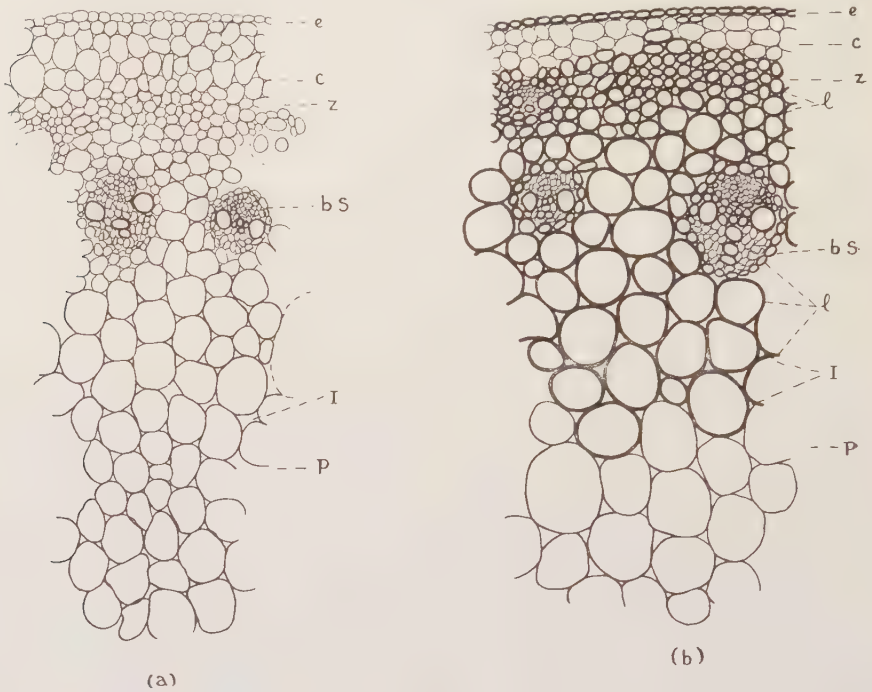


Figure A.

Transverse section of the stem of oat plants harvested on September 5th, 1939:—

(a) Control plant suffering from a deficiency of copper.

(b) Plant from adjacent plot receiving 30 pounds of bluestone per acre.

e = epidermis, C = cortex, Z = zone of lignified cells in cortex, b.s. = thick walled cells of the bundle sheath, I = marked intercellular connections of the outer pith cells, P = pith cells.

Magnification x 79 (camera lucida).

stem (a) of a control plant suffering from a deficiency of copper and (b) of a plant growing on soil receiving 30 lbs. of bluestone per acre, in addition to the usual phosphatic dressing. The section shows that the stem of the treated plant has a thickened epidermis (e), a zone of lignified cells in the cortex (c), thick walled cells of the bundle sheath (b.s.) and thickened walls with well marked intercellular connections (I) of the outer pith cells (P). In contrast to this, the stem of the deficient plants has a thin walled epidermis and in the cortex there is a similar zone of cells (Z), but these are thin walled and unlignified; the cells of the bundle sheath and pith are also thin walled. In the root there is also a lack of lignification of the walls in the deficient plants.

With respect to the leaves, figure B shows the chief difference in anatomy between the control and treated plants. The leaves of the copper treated plants have well differentiated motor cells (m.c.), numerous and usually lobed mesophyll cells (me), fairly abundant sclerenchyma (Sc) and thick cuticle (cu). The deficient plants show very little differentiation of the motor cells, smaller and more compact mesophyll cells forming a rather palisade-like mesophyll and usually fewer fibres; the cuticle is poorly developed.

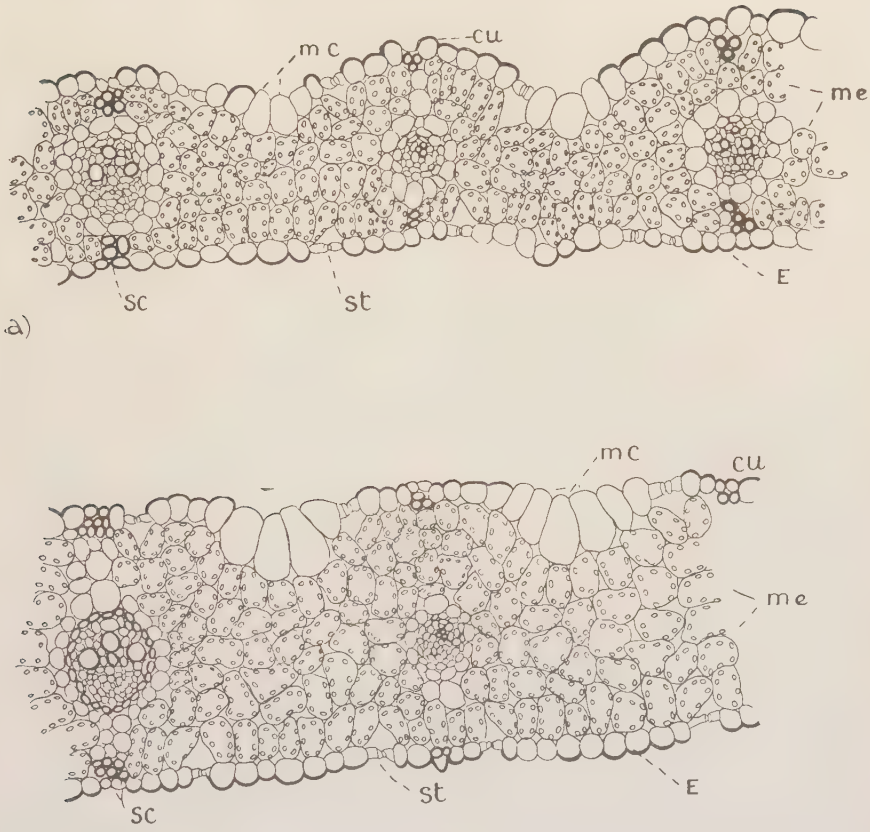


Figure B.

Transverse section of leaf of oat plants:—

(a) from control plot and suffering from copper deficiency;

(b) from adjacent plot receiving 30 pounds of bluestone per acre.

cu = cuticle, E = epidermis, m.c. = motor cells, Sc. = sclerenchyma, St. = stomate, me = mesophyll cells.

Magnification x 104 (camera lucida).

Where yellowing of the leaf and withering of the leaf tip occurs there are marked changes in the cell contents. The chloroplasts disintegrate and the cell contents change from green to yellow, and finally to brown tannin-like globules.

This investigation does not render it possible to say much about the chloroplasts at this stage. There was no definite evidence that malformation of the mesophyll cells or disintegration of the chloroplasts was greater in the control plants than the treated plants, except where withering of the leaf tips had already occurred.

The development of the hairs along the leaf edges showed marked differences which correlate with the soft feel of the copper deficient plants in comparison with those receiving adequate supplies. Figure C shows the leaf edges and illustrates the relative development of hairs in the two types. It will be noticed that in the copper treated plants the hairs are numerous and regularly spaced, but the deficient plants have fewer and smaller hairs which are irregularly spaced. This difference in hair formation was noted in other parts of the plant. A poorer development of root hairs and hooks on the ligules of the controls correlates with the relationship observed with respect to the leaf hairs.

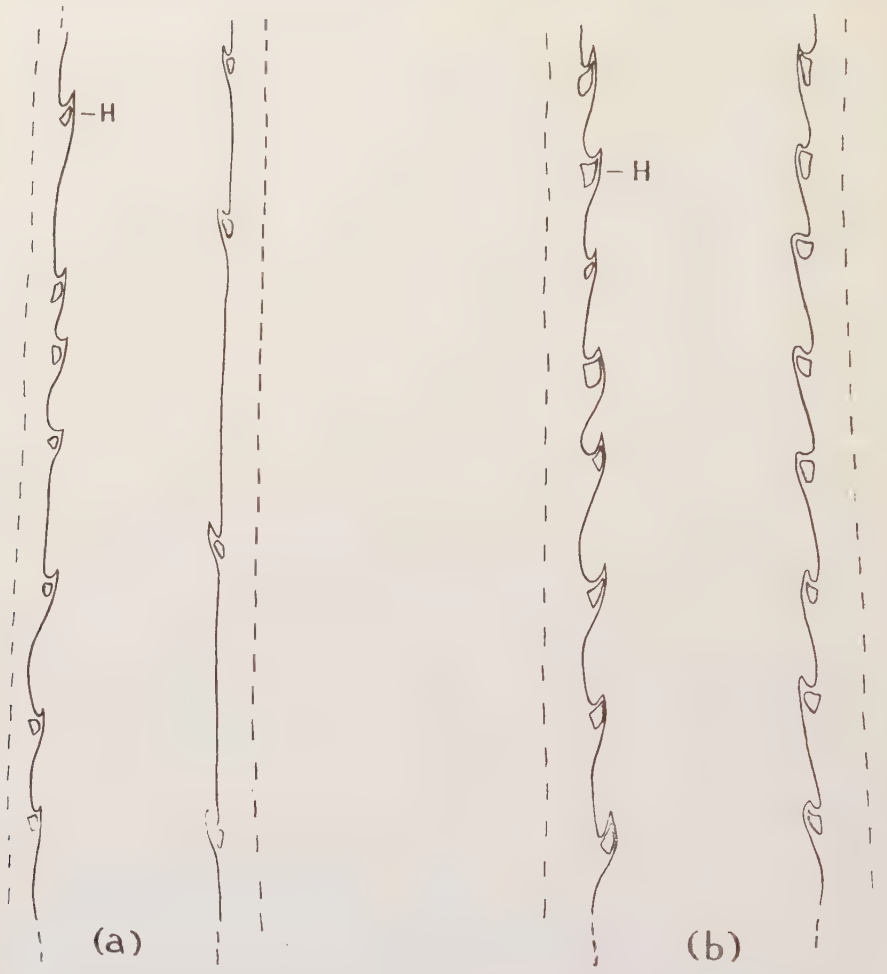


Figure C.

Silhouettes of the hairs on both edges of the leaf:—
(a) from a control plant;
(b) from a plant receiving copper at the rate of 30 pounds of bluestone per acre.

Magnification x 132 (camera lucida).

Discussion.

The above results represent only a preliminary investigation, but several anatomical differences are apparent, the most striking being the relative degree of lignification of the copper deficient and copper treated plants. The lack of thickening of the cell walls of the plants growing on copper deficient soils probably accounts for their limpness. Furthermore, the leaves show characteristic differences in hairiness and development of mesophyll and motor cells. Other minor differences were noted but further work is required to establish these, as well as the above anatomical differences, with respect to copper deficiency symptoms. It may be remarked that differences in leaf anatomy between the copper treated plants and the control plants also resembles differences obtained by growing plants in sunlight and shade. Furthermore, certain of these differences may be the result of arrested development—that is the failure of the plants lacking copper to continue their normal growth towards maturation.

Investigations of the anatomy of oat and other crops from other copper deficient areas of the State indicate similar results to those obtained with the oats at Dandaragan described above. Also, sections of plants from plots receiving 5 to 15 lbs. of bluestone per acre in the Dandaragan experiment were similar to those from plants from the plots receiving 30 lbs. per acre.

Irrigated Pasture Competition.

FINAL RESULTS.

H. G. Elliott, Agrostologist.

A. R. Clifton, Officer-in-Charge, Irrigation.

This competition was inaugurated by the Harvey Agricultural Society in 1937. A resume of the results of the first and second years' inspection is given in the March 1938 and 1939 issues of this Journal. The object of the competition was to stimulate interest and to demonstrate methods proved successful in the management of irrigated pasture, particularly the necessity for adequate drainage.

This competition embraces the whole of the irrigation area extending from Waroona to Dardanup. The Agricultural Societies of Waroona, Harvey and Brunswick, together with the Waterloo P.P.A., also ran individual annual competitions, embracing the entries from their respective districts. In these competitions it was arranged that the pastures were to be judged twice yearly for a period of three years, and the competitor gaining the highest total number of points for all inspections was to be judged the winner.

Messrs. Cuming Smith Mount Lyell Farmers Fertilisers Ltd., generously donated a trophy valued at 10 guineas to the winner, to be presented at the conclusion of the competition. The individual Societies also awarded annual prizes for the winners in their areas.

The results of the 1939 inspections which were carried out during the months of June and December have been combined, and the results given in the following table:—

TABLE 1.

Competitor.	Mixture. (20)	Sward and Uniformity. (20)	Condition. (20)	Management. (20)	Layout for Irrigation and Condition of Channels. (20)	Total Points. (100)
J. Salerian, Waroona (No. 2)	18	18	17	15½	15½	84
C. E. Edwards, Waterloo (No. 1)	17½	17	17½	13½	18½	84
J. Salerian, Waroona (No. 1)	16	17½	16	15	15	79½
C. E. Edwards, Waterloo (No. 2)	15	16	15½	11	15½	73
L. Temple, Harvey (No. 1)	16	16½	13½	14	13	73
L. Temple, Harvey (No. 2)	16	16½	13½	14	13	73
E. Holthouse, Harvey (No. 1)	16½	16½	15½	12	11½	72
E. Holthouse, Harvey (No. 2)	17	16½	15	11½	11½	71½
D Moore, Roelands	15	16	14½	12	14	71½
C. F. Giblett, Harvey	17	16	13½	9½	14	70
F. Reeves, Brunswick	15	14½	12½	10	11½	63½
S. Bowers, Brunswick	14½	14	11½	10	12½	62⅝
W. C. Edwards, Burekup	12½	12	11	10½	16	62
H. Piggott, Brunswick	15½	14	11⅛	7½	11½	60
L. C. Hynes, Waterloo (No. 2)	14	14½	11½	7	12	59
L. C. Hynes, Waterloo (No. 1)	13½	14½	11½	7	12	58½
T. P. Harris, Waterloo	12½	12	9½	10	14¼	58¼
T. Tyrell, Waterloo	11⅛	11	9½	7½	11	50½

It will be seen from the above table that the winners of the annual prize awarded by the Agricultural Societies conducting the competition are as follows:—

Waroona Agricultural Society—Mr. J. Salerian, No. 2.
Harvey Agricultural Society—Mr. L. Temple, No. 1.
Brunswick Agricultural Society—Mr. D. Moore.
Waterloo P.P.A.—Mr. C. E. Edwards, No. 1.

It was evident from the inception that the number of entries received indicated that the settlers in these districts were keenly interested in the development of irrigated pastures. It can be said that generally, the pastures exhibited were good, some of them being capable of carrying approximately 1 cow to ¾ acre, where adequate conservation had been carried out. Results such as this have been achieved only by careful attention to watering, manuring and reasonable management of grazing in rotational methods. During the second year of the competition additional entries were received in the Waroona and Waterloo areas for the annual section of the competition.

From Table 1 it will be seen that Mr. J. Salerian of Waroona and Mr. C. E. Edwards of Waterloo, gained the same number of points to tie for first position for the two inspections during the final year. The pastures exhibited by both these men were of a high standard on the basis of a system of White Clover with Perennial Ryegrass and in the case of Mr. J. Salerian, the addition of Cocksfoot. Subterranean Clover, Lotus major and odd plants of Yorkshire Fog were evident as minor constituents in the pasture. In one or two isolated parts, couch grass had shown up, this being present in most of the irrigated pastures judged.

Table 2 gives the results of the six inspections, 1937, 1938 and 1939:—

TABLE 2.

Competitor.	1st Inspection.	2nd Inspection.	3rd Inspection.	4th Inspection.	5th Inspection.	6th Inspection.	Total
J. Salerian (No. 2)	70	71	87	87	89	79	483
C. E. Edwards (No. 1)	78	82	79	74	83	85	481
J. Salerian (No. 1)	69	60	72	79	82	77	439
D. Moore	64	73½	78	76	78	65	434½
E. Holthouse (No. 2)	69½	75	72	73	75	68	432½
L. Temple (No. 1)	73½	62	76	67	74	72	424½
L. Temple (No. 2)	73	61	76	68	74	72	424
C. E. Edwards (No. 2)	64	76	71	63	79	67	420
E. Holthouse (No. 1)	71	50	68	75	72	72	408
S. Bowers	60	59	68	68	65	60	380
C. F. Giblett	57	47½	64	65	70	70	373½
F. Reeves	63	61	58	59	67	60	368
T. P. Harris	55	77½	54	60	57	59½	363
W. C. Edwards	47	52½	58	66	67	57	347½
H. Piggott	49½	56½	53	67	58	62	346
L. & C. Hynes (No. 2)	49½	50½	50	59	56	62	327
L. & C. Hynes (No. 1)	53	45	50	59	55	62	324
T. Tyrrell	55	51½	59	48	53	48	314½

This table shows that Mr. J. Salerian's No. 2 entry gained the highest total points for the six inspections, and consequently he is the winner of the trophy donated by Messrs. Cuming Smith Mount Lyell Farmers Fertilisers, Ltd. Mr. Salerian is to be congratulated on his excellent management of this pasture. The field has been approximately rotationally grazed throughout, at intervals between grazings varying from 14 to 24 days, according to the season and growth recovery of the pasture species. This method of grazing which has, and is being practised by this farmer, leaves little to be desired, except that it may be considered his time between grazings during the flush period could be lengthened to 15-20 days, and it is also thought that during the slow growing periods, i.e., the winter

months, up to 28 or 30 days may be more beneficial than the present 24-day interval between grazings as adopted by Mr. Salerian. At present we are unable to give definite information as to the best length of time between grazings. We have indications from experiments being conducted, that during the flush periods of growth 15-20 days are more beneficial than longer periods between grazings. Full information on this subject will not be available until the conclusion of the experiments which are being carried out by this Department at present.

Renovation is carried out annually, and pasture harrows are used fairly constantly during the winter months. Topping with a mower is also carried out when required. The following factors have been obtained from the inspections which have been carried out twice yearly for a period of three years:—

1. The most important feature noticed was the fact that in every case good strains of pasture grass and clover seeds were used.

2. In many instances mistakes were made in laying down pastures too soon before the land was sufficiently well prepared. For an important crop like permanent pasture, which with proper management will be reproductive for many years, it is obvious that thorough and very careful preparation is essential to obtain the best results. It is recognised, however, that farmers generally in our irrigation areas in Western Australia have had very little time to fit their land properly for irrigation, and it is particularly interesting to note the improvement of individual farmers by comparing the layout of their initial irrigated pastures with the ones sown at a much later date.

Block showing irrigated pasture on the property of J. Salerian, Waroona, consisting of Perennial Rye Grass, Cocksfoot and White Clover.

3. It was generally found that the management of irrigated pastures had been more or less neglected, more particularly with reference to grazing, this being due to a great extent to the phenomenal growth of annual pastures during the

spring months. Quite a number of the competitors had left their irrigated pastures for hay, and consequently when the first application of water should have been given, hay was still on the ground. This caused a serious setback to the White Clover and meant a considerable opening up of the sward and the killing off of a number of the perennial grass species to occur. If farmers intend to cope with the prolific spring growth of these annual pastures by grazing, the irrigated fields should not be left for hay cutting, but should be cut early and conserved as silage. This operation would overcome the difficulties which follow hay making. Good recovery of the pasture species would occur before watering would be necessary. Consequently no opening up of the pasture would occur, thus preventing the entry of weeds and assisting in the checking of couch grass spread, all of which, if allowed, increase at the expense of the more valuable pasture species.

4. At the beginning of the competition the general application of fertiliser per acre was on the low side. Some farmers were applying as low as 2 cwts. per acre per annum. During the last year's inspection the fertiliser rates per acre used by the competitors varied from 3 to 7 cwts. per annum, applied in 2 to 4 applications, superphosphate being the principal fertiliser used. In one or two cases, however, small quantities of sulphate of ammonia and potassic fertilisers had been applied.

The amount of superphosphate required on irrigated pastures per annum has not as yet been accurately determined by this Department under our existing conditions. Experiments, however, have been conducted using rates from 2-7 cwts. per annum in applications varying from 1 to 5 during the season, a basal application of 2 cwts. in the autumn being given. The results of the experiment were not considered conclusive, but under irrigated conditions excellent returns have been obtained from applications of 6 cwts. per annum given in three dressings. The time of application is autumn and December to March inclusive prior to irrigation in the case of the summer application

So far as can be ascertained, from these experiments, no improvement or additional yield was obtained from those plots which had the spring application, together with the autumn application. Further experiments have now been designed and are under way to determine the effect of the varied rates of application together with the varied time of application. On the experiments carried out at Roelands, the initial application of fertiliser on the area was in the vicinity of 11 cwts. per acre. It was found, when comparing the cost of the fertiliser with the production of butter-fat obtained over the whole area, that the cost of the fertiliser was 1.6d. per lb. of butter-fat. A competition carried out during the same year over a number of farms, showed that the average superphosphate application was in the vicinity of 2 cwts., the cost being 1.7d. for fertiliser per lb. of butter-fat produced. From these figures it will be seen that the high rate of application on the experiments, although considered far in excess of what the average farmer could afford, was no more expensive than the average application being put on, as both cost in the vicinity of 1.6d. per lb. of butter-fat produced.

The general recommendation for the irrigated pastures is an application of fertiliser, superphosphate only being recommended except in the initial years of establishment. The quantity used should be between 4 and 6 cwts. per acre, given in two or three applications, the heaviest application being applied in the autumn. Up to the present time no obvious response has been obtained from applications of potash, and in those places where lime and sulphate of ammonia have been applied to irrigated pastures, no benefit has been observed. This does not mean, however, that at some future time lime and potash may not become a factor in our fertilising programme.

Renovation.

The amount of renovation carried out on the pastures judged during the three years varied quite considerably. In a few instances no renovation had been adopted. Consequently, the pastures showed quite an amount of irregularity in growth, this being due mainly to the non-scattering of animal droppings. An important factor in irrigated pasture improvement is some form of mechanical renovation, the objects generally being threefold:

1. To aerate the soil.
2. To remove matted old grass and rubbish.
3. To enable fertilisers to come in contact with the soil.

The main advantage in the tearing up of the surface is the beneficial effect on the pasture, as it encourages the plant to produce fresh shoots and new succulent growth.

With reference to the sod type of pastures, more particularly paspalum, which often grow in irrigated areas, it is frequently noticed that unfavourable conditions for mixed pasture growth commence once the sward is well established, this being somewhere in the vicinity of four to five years after the initial establishment. In old, neglected paspalum pastures very little if any clover, and practically no paspalum growth is obtained. This position is brought about by dead root accumulation in the upper layers of the soil, which act as a thatch and interfere with the young roots and the aeration of the soil. To overcome this, it is necessary to use a good type of renovating implement. The use of chain or pasture harrows is also recommended during the winter months, this to spread and break up cow pats, which so frequently are seen on all types of pastures, Wherever these pats occur, rank growth of grass can be observed, and this is not eaten or relished by stock.

Irrigation.

All the pastures judged in the competition were laid out for watering by the furrow method. Some grading had been done but in the majority of instances the pastures had been sown on the most uniformly contoured portion of the farm without grading. The system generally adopted was the same as for irrigating potatoes and fodder crops. Under such conditions lateral seepage from furrows has been found to be reasonably rapid on account of the land having been freshly ploughed; but land laid out for irrigating pastures under such a system quickly becomes consolidated and compacted by the grazing stock and lateral seepage soon becomes too slow, with the consequent over watering of land adjacent to and along the furrows, while under watering occurs along the crown of the land.

At the time when these pastures were sown, however, there was little time and opportunity to do much grading, and under the circumstances it was the only system to adopt.

A power grader is now operating in the irrigation areas which is economically doing work which would not be feasible with teams on account of the high cost.

During the last two seasons, several hundred acres have been graded and land is being prepared for the control flooding of pasture under irrigation in all districts.

The system recommended is to lay the land out in long strips or borders at right angles to the contours so that the borders have a fall from end to end but are level sideways. The water is let out of the head ditch on to the surface of

the land and spreads sideways to the check banks, then slowly traverses the field from top to bottom. The borders, being laid out in the direction of the heaviest fall, provide the maximum run off for the heavy winter rains.

The following block shows the system in operation in the Collie Irrigation District.

Block showing border system of watering at Waterloo. Note water in the pasture.

Some Faults and Suggestions in Connection with the Grading of Potatoes.

E. T. MORGAN—Officer in Charge, Potato Branch.

This season (1939-40) has seen many condemnations of potatoes by reason of faulty grading. The faults complained of include second growth, greening by exposure and mechanical injury. The term "second growth" is understood by the majority of growers and is used to define tubers having abnormal malformation for the variety of potato. This so called second growth is generally manifested by protuberances or "knobs" generally from the original eyes of the potatoes, although it sometimes shows by elongation of the tubers with pronounced divisions of growth showing along the potato. These latter potatoes are often found in irrigated crops and show that the watering has not been carried out with due attention to maintaining an evenness of water supply. Again, it may be that unsuitable land for the growing of irrigated potato crops has been chosen. In the irrigation areas water is available only at certain set periods and land should be selected that will not tend to dry out during the periods between waterings.

Most growers would state that second growth is caused by weather conditions, i.e., by rains following dry periods during the time that the potato plants are nearing maturity and this is the generally accepted cause of the trouble.

There are, however, other contributing causes and these include Rhizoctonia and the over use of stimulating nitrogenous fertilisers. Regarding tubers from Rhizoctonia affected plants, the size of tubers and malformation of same will depend on the period in which the plants are most seriously affected. If such injury occurs in the early stages of growth, the tubers are generally small and malformed, but if, as is often the case, the attack is pronounced when the plant is nearing maturity, large tubers with much distortion are noted. It therefore behoves the grower to take such measures to control this disease as have been advocated by the Department of Agriculture for many years. The disinfection of seed, rotation of crops and the ploughing in of green material are effective in the control of the disease.

There is little doubt that much second growth, cracking and other malformation of tubers is caused by the too heavy use of nitrogenous fertilisers. It has been stressed on numerous occasions that the potato demands a well balanced fertiliser. Most of the mixtures that are quoted as potato manures are generally considered to be well balanced fertilisers.

It is usual in the growing of the spring crop in the South-West for growers to supplement the initial fertiliser mixture by top dressing the plants at emergence with sulphate of ammonia in order to replace some of the nitrates which may have been lost in drainage water.

The recommendation has been to apply 1½ to 2 cwts. of sulphate of ammonia per acre, but it is not unusual to find growers using from 3 to 5 cwts. per acre and in some cases applying a further dressing at a later period. These heavy dressings definitely lead to the unbalancing of the fertiliser mixtures and the results can be often observed in large ill-shaped tubers, caused by growth fluctuations of such treatment. The grower is ever chasing that 20 tons per acre crop, but if such is obtained with loss of quality the result is far from being satisfactory.

A further cause of so called second growth which has come to notice lately is evidently occasioned through extreme lightness of soil. This applies to new land in some of our very moist light peaty swamp areas. The potatoes are grown at a very shallow depth, almost in pure vegetable matter and such soil evidently does not offer sufficient resistance to expanding tubers and it has been noted that shape is detrimentally affected. There is of course little that can be done in such cases but as the land "settles down," correction of the trouble is to be expected. The rolling of the land may be necessary to allow of sufficient consolidation of the soil and slightly deeper planting may be advantageous.

Greening by exposure is a term with which most growers are familiar and it is a fault that all should take steps to obviate. Such potatoes are unfit for human or animal consumption, by reason of the poison solanin, which is developed by tubers in the process of greening.

There is little doubt that this greening can be avoided by attention to cultivation. Many of our so-called hill crop potatoes are grown in heavy soils and during wet weather conditions the soil is packed down by heavy rains, and as drier weather is experienced, much soil cracking by expanding tubers is apparent. Perhaps the tops have become too large, when weather conditions have been favourable, for effective horse cultivation, and the crop is left to carry on in its own way. Unfor-

tunately as the tops begin to die down the tubers that may have pushed their "noses" through the soil are deprived of shade and quick greening takes place. If sufficient width is left between the rows it is possible to carry out extra ridging or "moulding" at the period when the potatoes are nearing maturity with little or no injury to the crop, but with a definite saving from the viewpoint of quality; not only are the tubers protected from greening but also, to a great extent, from ready attack by potato moth larvae.

Mechanical injury is a term used to convey damage caused during the process of harvesting and generally applies to fork stabs. As well as fork stabs, such term is also used to define potatoes which have shown second growth and the protuberances or "knobs" have been broken off. In both cases the broken part of the tuber is liable under certain conditions to become invaded with various organisms (*Fusarium* and *Pythium* spp.) which will have the effect of causing rot in a very short space of time. So-called Watery Wound Rot (*Pythium de Baryanum*) will often cause tubers to completely collapse in 24 hours and it is not unusual to find that potatoes dug from peaty and other swamps during hot weather, which may be forwarded to market with every confidence by the grower as to quality, show a great deal of breakdown which has developed during transit to market. To avoid such trouble and the expense of picking over at the marketing end, it is advisable, if not possible to wait for cool conditions, to cart the potatoes from the paddock and regrade same after a week has elapsed. Tubers that are going to rot will collapse generally within a week of digging. Seeing that much damage eventuates from injury to tubers, regulations throughout the world are framed against such injured tubers being included in samples classed as Grade I. tubers.

The majority of our harvesting is carried out by fork digging and whether it is that the "good old type" of potato digger is dying out or the number of bags filled in a day is of greater concern, the result in many cases shows that the digger's work has not been carried out in a manner satisfactory to the grower who is paying him and who has to bear the brunt of his failure to do a job for which he is being paid.

Seeing that many growers have expressed dissatisfaction at results, it suggests itself that a remedy should be sought.

The alternatives seem to be (1) The tubers should be dug and afterwards graded; (2) The use of mechanical diggers. In America it appears that practically the whole of the potato crops are harvested and carted into sheds, where grading is carried out, on exactly the same principle that our fruit crop is handled.

Where an orchard has been planted, it is usual, as the trees near the bearing stage, for the orchardist to erect a shed for the purpose of handling his crop. I am afraid that many of our potato growers have no such facility for the handling of their crops.

The other alternative for lessening the amount of injury to tubers, is by the use of mechanical diggers. We know that such implements will not grade the potatoes, but the careful use of such implement will greatly minimise the injury to tubers. It is interesting to note that this year has seen great activity on the part of growers in the Albany area in the use of mechanical means for the harvesting of their crops and many farmers have expressed gratification at the work of the double mouldboard plough arrangement with the mouldboards replaced by prongs.

The failure to obtain satisfaction with such implement is of course reported (1) by reason of trashy ground; (2) over-wetness of soil and (3) many tubers being damaged.

It would of course be difficult to devise a machine which would operate under all conditions and when heavy weed growth has been ploughed in and decomposition has not been complete the attempted use of machinery is unsatisfactory by reason of "clogging." Over-wetness of soil may also act as a detriment but the cases quoted are rare, and judging by results witnessed this year, much can be said in favour of the mechanical type of harvesting. Injury to tubers is mainly due to the fact that the potatoes have been planted at varying depths and the set of the implement has not been able to cope with such varying conditions. There is little doubt if growers, contemplating the use of mechanical aids to harvesting, planted their crops with this end in view, that results would be satisfactory. Any mechanical digger operates most satisfactorily where the potato crop has been "moulded up" and such earthing up can be carried out as the crop is nearing a fit state to harvest. This method is used by Mr. F. V. Hortin of Hortin's Siding, who efficiently works an elevator type of digger.

It will, of course, be necessary to leave sufficient width between the rows for this operation to be carried out effectively. It is understood that top growth is often excessive, but it has been found that where such occurs, cultivation carried out when the tops are dry will allow the implement to travel between the rows without clogging, which will happen if the tops are moist.

Notwithstanding the foregoing, it is realised that the majority of the potato crop will be handled by fork digging, and it is suggested that, if growers wish to safeguard their interests in a greater degree, diggers should work under numbers.

This method is now being used by many growers, and if each digger's bags are numbered, it enables the grower to immediately designate the member whose grading is at fault. It is not unusual to find, in a truck of potatoes, bags which are in every way satisfactory, as to grade, while others leave much to be desired in this respect, plainly showing that the operations of certain diggers are not up to the required standard.

Potato grading regulations throughout the Commonwealth are asking for ever better quality and it behoves us to take the greatest care of our product so that it will compete more than favourably with that of other States.

REVIEW.

"Diseases of Poultry in New South Wales."

"Diseases of Poultry in New South Wales" by T. G. Hungerford, B.V.Sc., Government Veterinary Officer, Stock Branch, Department of Agriculture, New South Wales. New South Wales Department of Agriculture publication, 1939, *pp.* 230. *Price* 10*s.* 6*d.*

For some considerable time, in all progressive states and countries, it has been generally realised that diseases of poultry, no less than those of any other livestock, must be studied and dealt with along the accepted scientific lines applied by the qualified Veterinarian in meeting the disease problems amongst our larger animals. By virtue of his highly specialised training, which these days includes a full study of poultry diseases as far as they are yet known, the Veterinarian is the only one competent to deal thoroughly and efficiently with such matters and it is gratifying and timely to welcome the appearance of a publication by a Veterinarian who has for some years now, specialised in poultry work.

The author points out in his preface that the book "is not written as a technical treatise on poultry diseases" but it is "a popular account of symptoms, control measures, as well as an indication of what is still unknown concerning some

of the disease conditions." He goes on to state that "those who have only a passing interest in disease may find that the amount of detail given is somewhat irksome. This has been done intentionally, as a passing interest which leads one to make an ill-founded diagnosis and to carry out incorrect treatment will usually demonstrate that 'a little knowledge is a dangerous thing.'"

Although the title is "Diseases of Poultry in New South Wales" it will be found equally valuable under Western Australian conditions as there is no disease yet diagnosed here with which the book does not deal. Infectious Laryngotracheitis and Fowl cholera which are dealt with at some length have not yet been detected in this State.

If the publication only succeeded in teaching the poultry farmer to cease using the misleading and all embracing term "roup" and that medicinal treatment for infectious poultry diseases is seldom worth the trouble and expense involved, then it would have accomplished a good deal. The term "roup" is far too commonly used here and scarcely any farmer yet realises that it comprises five entirely different diseases of different cause, as well as several more obscure ailments. There are still many who will treat Avitaminosis A (green feed deficiency disease) with eye lotions and Coryza or Infectious Catarrh with medicated water.

This book deals with 74 different conditions of interest to the poultry farmer without any important omissions. For the purpose for which it is intended we feel that it is worthy of recommendation and except when dealing with the Leucosis group of diseases it is written in a style which the farmer will not find difficult reading.

L. W. MAHAFFEY.

White Clover,

by

H. G. ELLIOTT, Agrostologist.

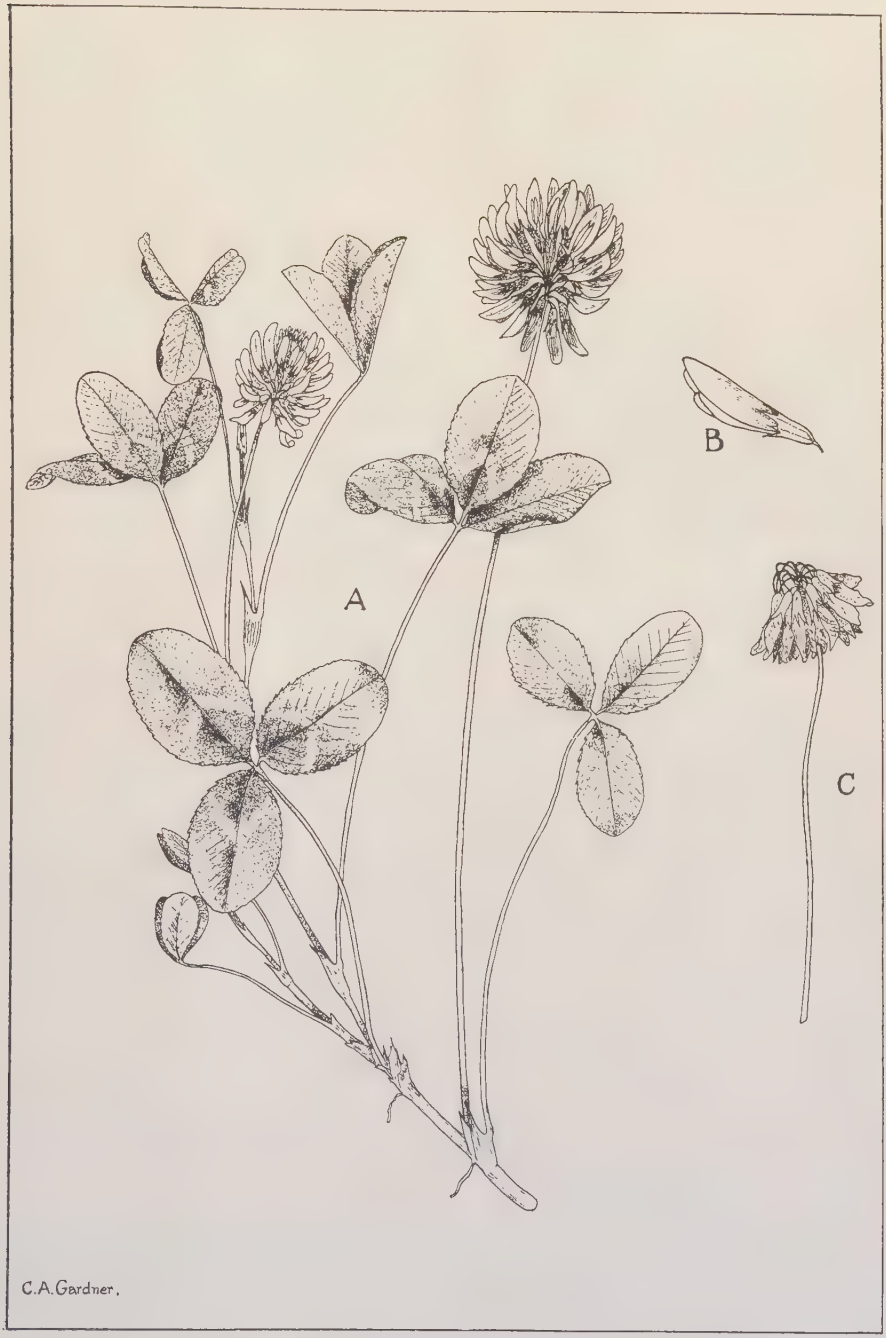
White Clover (*Trifolium repens*) has become a pasture legume of first importance in the irrigation areas of this State which extend from the Waroona district to Dardanup. This clover is also of great value on certain soil types along the south and south-west coastal regions.

White clover is indigenous throughout temperate Europe and Asia and the first seed was harvested in Holland, hence the name of that type today "White Dutch Clover."

Description of Plant.[*]

"A hairless perennial with prostrate rooting stems. Leaflets (3) broadly ovate and usually marked with a crescent shaped white stripe. (See illustration). Finely toothed margins but veins not very conspicuous. The flowers are white, but are pink when in bud and are loosely arranged in a head consisting of usually 30-40 flowers. The stalk of the head is generally longer than the leaves. Pedicels short and slender, reflex after flowering. Calyx glabrous ten-nerved with acute teeth usually erect. Standards twice as long as the calyx. Pod enclosed within the calyx oblong, slightly constricted between the three or four seeds."

*Description given by Mr. C. A. Gardner, Government Botanist.



White Clover.
(*Trifolium repens*, L.)

Explanation of Plate:
A.—Plant. B.—Flower (enlarged). C.—Fruiting head (enlarged slightly).

White clover is generally a fairly, and often a very long-lived, perennial. It forms a well developed mat of fibrous roots. Unlike Red and Alsike Clovers, it has solid stems which creep on the surface, rooting at the nodes so that the plants are able to colonise the ground freely by means of vegetative reproduction. Except under certain conditions it is not general for white clover to produce abundant top growth, consequently when cut for hay or silage the material consists almost entirely of leaves and flowering heads.

Strains.

A considerable number of forms or strains of white clover are to be found. These do not differ from each other in well marked characteristics. During the last ten years the value of strains in pasture grasses and clovers has received much scientific investigation and general recognition. The difference between variety and strain could be summed up as follows: Variety possesses structural variations, such as in the flowers or structural difference of the leaves and branches which makes it different from the original species type. A strain, however, has variable characteristics such as early or late flowering, long or short growing period, high or low production, variability in leaf denseness, steminess, etc., which are ascertained when carrying out comparative field tests. From an agricultural point of view, however, it is possible to make the following classifications:—

(1) White Dutch Clover of Commerce.

(2) New Zealand White Clover.

(3) New Zealand White Clover Government sealed and certified Permanent Pasture.

(4) Victorian Irrigation White Clover Dingee Government sealed and certified.

(5) Kentish Wild White Clover.

(6) Ladino Giant or Mammoth White Clover.

(1) *Commercial White Dutch Clover.*—This is grown for seed in Central Europe, Russia, Holland, Britain, Poland, Denmark and America. In general, much of this commercial seed does not give rise to a long-lived plant, and frequently only produces plants of biennial duration. This type generally establishes itself freely from seed, and is fairly productive during the first season. It flowers profusely during the first summer after the sowing, and normally early in the season. The leaves are of medium size and it is generally claimed where severe winters occur that it is a type which is a poor winter grower.

(2) *New Zealand White Clover.*—In characteristics, much the same as the Dutch type, except that it appears to be more vigorous and probably more persistent. This may be due to the inter-crossing of the ordinary imported type with the more productive and permanent white clover type.

(3) *New Zealand White Clover Permanent Pasture.*—Comparatively large-leaved, highly productive, widely spreading type, with stout runners, being dense and persistent. A good winter growing form, vigorous in the spring and holding well in the summer and early autumn.

(4) *Victorian Irrigation White Clover Dingee Certified.*—Comparatively recent introduction in this State. Experiments with this type indicate that it is slightly superior to the New Zealand permanent pasture type, being more vigorous, larger-leaved and producing a greater bulk of green material under irrigated conditions.

(5) *Kentish Wild White Clover.*—Similar in characteristics to the White Dutch type. The plant is very much longer lived and a more hardy perennial with a close creeping habit, producing numerous abundantly rooted runners, which carry large numbers of small leaves on fairly short stalks. Its flower-heads are fewer per plant and often smaller, and its seeds usually smaller and plumper than those of the White Dutch type. This clover is indigenous to Great Britain.

(6) *Ladino Giant or Mammoth White Clover.*—This type originated in North Italy. It is probably the tallest growing and largest-leaved white clover in commerce. The plant is lax in growth and it does not persist well.

Agricultural Uses.

Generally speaking, the ordinary commercial white Dutch clover should only be used in rotations, or as a constituent in mixtures sown for a two or three year duration, while the New Zealand white clover of permanent pasture origin and the Victorian irrigation white clover should in all cases be the types used in mixtures being sown for a permanent pasture. Of the six types given above, only two are grown to any extent in this State. Till recent years, the dominant types sown were the commercial Dutch and New Zealand white clover. Today, however, the type recommended and mainly sown is the New Zealand certified permanent pasture type. Neither the Kentish wild white nor the Ladino or Mammoth white are grown, but during the last season, some interest has been shown in the Victorian irrigation dingee type, owing to results which have been obtained in plot and field trials.

Where to Sow.

The areas recommended for the sowing of white clover, either alone or in mixtures with other clovers and grasses, are those where irrigation can be practised or in the high rainfall areas on soils which are comparatively well drained but retain their moisture during the summer months. These areas are often found in the Denmark, Manjimup and Margaret River districts. White clover is recommended as the standard legume constituent of our irrigated pastures. During recent years in our irrigation areas we have found that it will grow and thrive well on freshly graded land, and also is capable of establishment on new land, provided that the necessary bacterial inoculation has been given to the seed prior to planting. Experience has shown that this clover does well on a variety of soils, ranging from heavy clays to the lighter loam and in the higher rainfall areas on sandy and peaty types of soil. Particularly satisfactory results, however, are obtained on the medium and light loams.

Where lucerne flea and red mite infestation is high, it is not recommended that this clover be sown during the autumn months. Spring planting or early or late summer plantings are recommended, so that the young seedlings will have a chance to grow without suffering from the effects of these two pests.

It is also important from the point of view of keeping out weeds, that white clover should be established quickly, and as regards the fertility of the ultimate pasture, a relatively high content of white clover in the sward is advantageous, as it assists in building up the fertility of the soil. It has also been shown that the leaves of the plant are rich in both protein and calcium, so that a good proportion of white clover in a grass sward adds to its nutritive value.

Time of Sowing:

As stated previously, it is not recommended to sow white clover in the autumn, unless on new land or land which has been freed to some extent of Lucerne Flea and Red Mite. Under irrigated conditions, it is recommended to sow in the late

spring or early or late summer, so that establishment will be obtained prior to the ravages of the Lucerne Flea and Red Mite commencing. When sown in the early or late summer, it is necessary to carefully water by irrigation at about ten day intervals, until the plants are able to withstand longer intervals between watering, up to three weeks.

Cover Crops:

From experiments which have been conducted in the irrigation area, it has been definitely shown that quick growing cover crops are detrimental to the early establishment of white clover. Such types of cover crops as Millet, Sudan or Oats do have the effect of suppressing the young white clover seedlings, and consequently, it may be upwards of two years before a full cover would be obtained. In the interim, however, weeds such as couch grass are liable to take charge of the area at the expense of the white clover. In some cases, where high rates of seeding with Ryegrass have taken place in mixtures in which white clover has been incorporated, much slower rate of establishment has been obtained, and in many cases up to two or three years elapsed before a reasonable ground cover of white clover occurred. Consequently, it is not recommended that any form of vigorous growing cover crop be used when establishing pasture in which this plant is a constituent.

Mixtures and Rate of Seeding:

It is usually recommended that white clover be planted in association with Ryegrass and Cocksfoot, or Ryegrass and Paspalum. In some instances, however, pastures of two species are established, these being ryegrass and white clover or *Phalaris tuberosa* and white clover. In all cases it is recommended that no more than 2 lbs. of white clover seed be used, providing reasonable attention and care has been given to the preparation of the land. For obtaining information as to rates of seeding, etc., Leaflet No. 601 on the "Sowing of Pasture Seeds" can be obtained.

Method of Seeding:

Results have shown that for the best results the seed should not be sown to a greater depth than ¼ to ½ inch. The usual method recommended is to sow this seed in a finely worked seed-bed in combination with the other seeds in the mixture, the area to be rolled after seeding, or very lightly harrowed. Whatever system is adopted, it is advisable to use a brush-harrow afterwards. The soil cover of the seed is beneficial, but not absolutely essential, as this clover is one of the few which will germinate and grow without soil covering. In order to spread the seed evenly, it is recommended that a small seed sower, such as the hand seed sowing types of machines be used. If these are not available, and providing the seed is not mixed with the fertilizer too long prior to planting, the seed can be distributed evenly by any fertilizing machine. Where inoculation of the seed is being carried out, it is not recommended to broadcast the seed in combination with the superphosphate.

Inoculation:

As is the case with other plants belonging to the Legume family, white clover has the ability to use atmospheric nitrogen for growth, but only when the proper bacteria, which vary for different groups of plants, are present. In some cases, however, when white clover is planted on old land which has grown subterranean clover or other annual clovers of the *Trifolium* species, inoculation may not be required, and in many of the districts in the irrigation areas, inoculation is not

practised, but where new land, or freshly graded land is being sown to White Clover, inoculation prior to planting is essential. For this purpose, bottles containing bacteria for inoculation together with directions for use are provided by the Department of Agriculture at a nominal cost. Seeds, once they are inoculated, should not be mixed with superphosphate prior to planting, as it has been shown that the superphosphate injures the bacteria. For best results, however, it is essential that the inoculated seed be sown at the same time as the superphosphate, but where no contact is made. When sowing this inoculated seed, it is essential that the ground should be wet at the time of sowing.

Fertilizer.

For best results, fertilizer in the form of superphosphate is essential to the success of this clover. The superphosphate should be applied at the time of seeding, at a rate of 2 to 3 cwts. per acre, and at regular intervals thereafter. When white clover is established, the best time for the application of the superphosphate is early autumn, i.e., April, at a rate in the vicinity of 2 to 4 cwts. per acre. This heavy rate of fertilizing in the autumn appears to give the most economical results. Further applications of 1 cwt. per acre can be given in November and February, prior to irrigation.

Management.

One of the important phases of an irrigated pasture is the control to some extent of white clover. A dominantly leguminous sward presents some difficulties. During the irrigation season this clover provides the bulk of the herbage over an extended period, and with the attention paid in recent years to the watering and top-dressing, white clover has to some extent been encouraged to the point of nearly excluding all the other species, with consequent difficulty in maintaining a good grass-clover balance. For some time it has been observed that in a mixed pasture the grazing system employed profoundly influences the balance of the various species. The general aim should be to retain a desirable balance between the species, and particularly between grasses and legumes. This should

Block showing a pure stand of White Clover, New Zealand certified type, grown under irrigation at Brunswick.

result in a better production throughout the year, and further the herbage in a well balanced sward should be more palatable. During the first year of establishment, care has to be taken not to over-graze the white clover; quick grazing with a number of stock at intervals sufficient to allow the clover to recover and produce reasonable top-growth should be practised. After the first year of establishment, experiments have shown that the best method of maintaining the clover in association with such grasses as Cocksfoot, and Perennial Ryegrass, is to ensure that the grazing periods are not closer than approximately 21-day intervals. During the cold and wet portions of the year, this period may have to be extended to 30 days. Where severe over-grazing occurs, more particularly during the summer months, there is a tendency for the pasture to become open, allowing an increase of weed species.

On old paspalum fields, which have become practically non-productive owing to being root-bound, the introduction of a suitable legume is essential. For this purpose white clover can be used. It is recommended that the paspalum be ploughed with a mould-board plough and after the surface has been worked down, white clover at the rate of 2 lbs. per acre and perennial ryegrass at 4 lbs. per acre be introduced. This method has been adopted on a number of fields in our irrigation areas with success.

Summary.

From the foregoing, the following may be summarised as of first importance:

(1) Of the types of white clover, the seed of which is available, the New Zealand certified permanent pasture white clover and the Victorian certified irrigation white clover are recommended for use in permanent pastures.

(2) White clover has demonstrated its ability to produce better than subterranean clover under irrigated conditions.

(3) Inoculation is essential on new or graded land.

(4) Shallow sowing is desirable.

(5) Dense, heavy producing cover crops are detrimental to the initial establishment of white clover.

(6) It is not recommended to exceed more than 8 lbs. per acre of Perennial Ryegrass when sown in association with white clover.

(7) Under irrigated conditions, high rates of superphosphate applications per acre are profitable.

(8) The proportion of clover or grass in the pasture can be affected by the grazing management.

Ragwort.

(Senecio Jacobaea L.)

A NEW NOXIOUS WEED.

C. A. Gardner.
Government Botanist.

The importance of the early recognition of a serious weed, and its prompt destruction has been demonstrated very clearly in the case of ragwort in Western Australia. In January of this year a specimen of ragwort was received at the State Herbarium from the secretary of the Manjimup Road Board, who stated that Mr. J. J. Mottram noticed an unusual plant on his holding, and, suspecting that it might be a weed of some consequence, had handed a specimen to him to be forwarded for determination. This specimen was the first record of ragwort in Western Australia. An officer immediately visited the district to investigate the reported occurrence, and found that the affected area comprised about one hundred square yards in a pasture paddock where the large trees were dead but still standing. The plants of ragwort were mainly clustered together and had the appearance of having originated from a single, or but few associated plants.

The history of the occurrence of the weed suggests that the seed was introduced from New Zealand, together with the seeds of pasture plants from that source, about five years previously. The prompt recognition of a weed by Mr. Mottram, and the interest and co-operation of the road board, have resulted in what is hoped will be the suppression of this plant in Western Australia. Specimens of the weed were deposited with the secretary of the Manjimup Road Board for exhibition, in order that the plant might be recognised by others. The result was the detection of another small occurrence on a property not far removed from the original area.

Ragwort has been proclaimed in the *Government Gazette* as a noxious weed for the State of Western Australia, and the two known affected areas have been grubbed. A close inspection of these spots will be maintained at intervals, and settlers, especially those in the Denmark-Northcliffe districts, are urged to be on the look-out for the plant.

Ragwort is a perennial herb native to Europe, Siberia and North-Western India, but is recorded as a naturalised alien in North America, New Zealand, and Victoria. It is toxic to stock. In New Zealand large areas have become infested—in places to the exclusion of most other vegetation .

In addition to the fact that ragwort is a robust perennial capable of reproducing itself vigorously from its roots, it is also a remarkably free-seeding species adapted for rapid proliferation. The seeds may lie dormant in the soil for some years, and germinate when conditions prove favourable. It is because of this latter characteristic that some years must elapse before complete extermination can be claimed with certainty.

Toxicity.

Ragwort has been proved toxic in Britain, in Canada, New Zealand and Victoria. Horses and cattle are most likely to be affected, and the slow poisoning of dairy cattle has caused much concern. The toxic effect is cumulative. Poisoning under natural conditions is a slow process because an animal does not usually eat enough of the weed at one meal to cause acute poisoning; on the other hand, through its cumulative action the amount of poison which becomes available is sufficient in time to cause very serious symptoms which often end in death.

Murnane* states that after grazing for twelve months or more on areas where ragwort is plentiful, cattle develop typical symptoms, exhibiting dullness, loss of appetite, and a jaundiced condition of the eyes, together with a peculiar staring appearance. There is loss of weight and, in the case of lactating animals, a very marked diminution of the milk supply. The milk has a peculiar odour and a pronounced acrid flavour rendering it quite unfit for use. The affected animal frequently exhibits a scabby condition of the skin, especially in the udder and teats. In the later stages there is impaired vision, staggering gait, persistent diarrhoea, a marked thirst and progressive loss of condition. The milk supply ceases, food is not taken, the animal becomes weaker, drops down and eventually dies—frequently in a swamp or water hole into which it has wandered in order to quench its insatiable thirst.

The actively poisonous agent in the plant appears to be one of two or more alkaloids which have been extracted in more or less pure form from various species of ragwort. It would appear that, although animals which had received a toxic amount of ragwort over a certain period, may seem healthy at the time when feeding on the material is discontinued, they nevertheless develop acute symptoms of poisoning and die at a later period. Thus, in cases investigated in Britain some of the animals did not show definite symptoms until twelve days or more after feeding tests with ragwort had been discontinued.†

There is no cure for ragwort poisoning, and prevention resolves itself into the eradication of the plant. Sheep are less affected than cattle and horses, and when managed correctly provide a practical measure of control.

Eradication and Control.

The prevention of seed-formation on the plants is a very important factor in the control of ragwort. Where only a few plants occur, careful grubbing represents the most safe method of control. The roots and the entire rootstock should be removed, heaped and burned, this operation being carried out before the flowers have expanded, since any flowers present on severed plant parts may develop mature seeds because of the sappy nature of the stems; consequently every part of the plant should be destroyed.

Since the seeds retain their vitality in the soil for a number of years, one year's seed production will necessitate a careful examination of the infested area for several years after grubbing. Spasmodic cultivation only serves to divide the rootstocks and spread the weed. Any cultural work must be thorough and repeated as often as necessary, and it is important that the affected area should be treated as a unit in this connection.

Where the plant is abundant and widespread, sheep have proved a practical means of control. This method has been attempted in many places in New Zealand with success and has resulted in practically no abnormality amongst the sheep, but, on the other hand, mismanaged efforts on the part of other settlers have resulted in failure with heavy stock losses. Given proper treatment, a measure of control has been secured in two or three years. Very good results have been achieved by stocking heavily with sheep when the ragwort is young and juicy. Small paddocks are desirable, and old animals have been found to be less affected than lambs, and at the same time more severe in their grazing.

Both sodium chlorate and arsenic pentoxide have proved effective when sprayed on ragwort, complete destruction having been obtained from the application of a five per cent. solution of sodium chlorate. This treatment by sodium

* Ragwort Poisoning in Cattle in Victoria—W. Murnane, Journ. C.S.I.R., Vol. 6, pp. 108-110.
† Report of the Board of Agriculture's Chief Veterinary Officer (1917).

EXPLANATION OF PLATE.

A. Habit of plant showing stock and basal leaves, also the apical portion with stem leaves and flowers. About sixteen inches from the middle has been removed. B. Stock with a rosette of basal crisped leaves. C. Radical leaf. D. Flower-head. E. The same showing the involucre of black-tipped bracts. F. Disc floret. G. Ray floret. H. Fruit ("seed").

Northcliffe, W. Australia. January, 1940.

chlorate has proved more effective during showery weather than during particularly dry weather, and Dean* states that as the plant reaches the flowering condition a weaker solution than that required while the plant is actively growing may be used. An application as low as two per cent. has proved effective when applied to plants in flower. The chemical control of weeds is, however, an expensive method, and usually is not economical for large areas.

Description of Plant.

Ragwort grows to a height of from two to three feet, from a short thick rootstock which divides with age. The stems are strictly erect, simple or branched above, and usually a bright purple in colour. Leaves pinnate, with ovate, obovate or narrow coarsely toothed or pinnatifid segments, the terminal ones large and confluent, the lower smaller, all glabrous or loosely downy, especially on the lower surface; basal leaves on long petioles, the uppermost sessile. Flowers yellow, in compact or broad terminal corymbs; involucral bracts linear, tipped with dark brown or black points, the outer bracts few and very small. Ray florets yellow, usually 12 to 16 in number, linear-oblong, spreading; disc florets numerous, yellow. Achenes of the disc florets shortly and coarsely hairy, the achenes of the ray florets glabrous.

For further particulars see the accompanying plate. The young plants have dense crisped radical leaves and the thick stock develops early, the stems in the local plants are purple in colour.

* Control of weeds with chlorates—J. W. Lean, New Zealand Journ. of Agric., Aug. 20, 1931.

Agricultural Problems.

Agriculturists, pastoralists and primary producers generally, who may be having difficulties of any kind in connection with their production activities, are invited to communicate with the Agricultural Adviser or Veterinary Officer of their district of the Department of Agriculture, when information and advice will be supplied free of charge.

Where identification of plant or stock diseases or insect pests is required, full details of symptoms should be forwarded and also samples of the diseased plant, animal tissue or insect where practicable. Plant tissue intended for examination by the Plant Pathologist should be wrapped in paper and not forwarded in airtight containers, and plant specimens for the Botanist should be pressed between newspaper and dried before despatch. With regard to animal tissue for microscopic examination, this should be forwarded in a solution of 10 per cent. formalin, or if of considerable bulk in a sealed kerosene tin containing a few ounces of formalin as a preservative. Living insects should be sent in suitable containers and dead specimens in methylated spirits.

The addresses and names of Advisers are as follows:—

Albany	A. T. Gulvin, W. R. Jamieson (Fruit).
Bridgetown	A. M. Tindale (Dairying), A. Flintoff (Fruit).
Bunbury	M. Cullity (Dairying), A. F. Flood (Stock Diseases).
Busselton	J. M. Nelson (Dairying).
Denmark	C. W. Tobin (Dairying).
Geraldton	N. Davenport, c/o. Government Buildings.
Gosnells	R. C. Owen (Fruit).
Harvey	R. C. Cailes (Fruit).
Katanning	A. S. Wild.
Kalamunda, Roleystone ..	W. H. Read (Fruit), c/o. Dept. of Agriculture, Perth.
Kununoppin	W. M. Nunn.
Manjimup	J. T. McNally (Dairying).
Margaret River	A. L. Hamilton (Dairying), R. Harley (Stock Diseases).
Metropolitan, Gingin, Chittering	S. E. Bennett (Fruit), c/o. Department of Agriculture, Perth.
Moora	G. L. Throssell.
Mundaring	V. Cahill (Fruit).
Pemberton	C. M. Scott (Dairying), Manjimup.
Pinjarra	B. Williams (Dairying), c/o. Department of Agriculture, Perth.
Waroona	A. H. Hobbs (Dairying).

Lucerne Growing in Western Australia,*

by

H. G. ELLIOTT, Agrostologist.

Summary.

(1) Lucerne has been grown for many centuries, and consequently is well known in most of the agricultural countries of the world. As far as can be ascertained it was introduced into Australia just after the first settlement by white man and since that time has made considerable progress.

(2) Lucerne flourishes in semi-arid climates, but for maximum growth requires abundant water during the summer months. Consequently, it grows best where supplemented with irrigation.

(3) Of the many varieties of Lucerne, the most important in Western Australia are:—

Australian Hunter River.

Californian.

Hairy and Smooth Peruvian.

(4) For best results only high quality seed should be used.

(5) Lucerne has many peculiarities and troubles, being somewhat delicate when young, and of all crops is the most sensitive to competition from other plants, consequently the secret of success is to keep down weeds during the first year.

(6) Lucerne will not tolerate soils which become water-logged.

(7) This plant does not need, as many assert, abundance of lime in the soil, but freedom from acid is essential. Soils that are deficient in lime, however, should receive applications of agricultural lime prior to the planting of the lucerne.

(8) Innoculation of the seed with the necessary nitrogen-fixing bacteria prior to planting is essential.

(9) The ideal seed-bed for lucerne should be firm, but with a fine tilth to a depth of about 1½ inches.

(10) The best fertilizers are superphosphate and potash, the rates of application per acre varying according to districts.

(11) The land must be clean, for weeds are difficult to eliminate once the crop is sown.

(12) The best method of seeding is by drilling the seed into the land, but the seed should not be sown to a greater depth than ¾ inch.

(13) The best time to sow in this State is in the autumn or spring. In the south-west, spring is probably the best time, as it allows time for the control of Lucerne Flea and Red Mite, and late cultivations to kill weeds.

(14) According to districts and methods of planting, the seeding rates vary from 2 lbs.-12 lbs. per acre.

(15) Cover or nurse crops are not recommended or required.

(16) Farmyard manure stimulates lucerne, but should always be well rotted prior to application.

* Revised from an article on "Lucerne, The Queen of Fodder Crops," by G. L. Sutton, late Director of Agriculture, which appeared in Vol. 14, Second Series, No. 1, March 1937 issue of this Journal.

(17) When seed is sown in drills, the width between drills is determined by the weed difficulty. In the wheatbelt normal drill widths are recommended. In the coastal areas 24 to 30 ins. between drills is advisable.

(18) If the first year stand is thin, the weak patches should be re-seeded while the plants are young, otherwise it is difficult to make an even stand.

(19) Lucerne produces very heavy crops of fine textured forage, rich in protein, lime and other minerals suitable for all classes of live-stock.

(20) For best results from good stands of lucerne, it should be cut and not grazed. Under this system of management the stand will persist much longer.

(21) Experience shows that the plant, once established, can be heavily harrowed and cultivated to reduce weeds and mulch the surface soil.

(22) The time to cut lucerne for hay is when the new shoots have started from the crowns. This usually coincides with the flowering period.

(23) Lucerne leaves have a much higher value than the stems. Consequently great care should be taken, when making hay, to ensure that all the leaves are saved.

Introduction.

Lucerne is one of the oldest of the cultivated forage plants, and is one of the most important agricultural crops known to man. It flourishes in semi-arid climates, and although it gives best results where ample water is available, it can however, grow well wherever cereals are profitably produced in these climatic conditions. Besides being one of the hardiest of the known agricultural crops for hot dry conditions, it is one of the most palatable and nutritious foods for livestock, including all farm animals and birds, as they can maintain themselves and thrive on it. The crop has been cultivated for centuries in the semi-arid portions of Asia, as well as in parts of Europe, and in all places it produces an abundance of fodder of the highest quality, improves poor soils and assists in eradicating weeds. This plant can be successfully grown on a variety of soils, which range from loose sands to relatively heavy clay loams.

History.

Lucerne has been cultivated for thousands of years, and was introduced into Greece during the Persian Wars (about 490 B.C.) to provide forage for horses and cattle of their armies. It was taken to Spain with the Moors under the name "Alfalfa." The Spaniards introduced it to Mexico and from that country it spread over South America and extended to the United States and Canada. In Canada and America lucerne is known and cultivated as "Alfalfa." This word is believed to be of Arabic origin, and derived from words which mean "the best fodder." It will thus be seen that its great value for fodder purposes has been long recognised, and the splendid reputation which this plant so early earned and which by its name has come to us down through the centuries, is still maintained.

It is thought that the name "lucerne," by which it is known in England and France, was derived from the Swiss canton of the same name, but Coburn in "The Book of Alfalfa" considers this to be a mistake, as it was not known there until long after it was cultivated in France and England. He states that "the name 'Lucerne' is probably derived from the Spanish word 'Userdas,' which the French changed to 'La cuzerdo' and later to 'Luzerne' and still later to 'Lizerne' and then to 'Lucerne'."

Lucerne was probably brought to New South Wales by the earliest military settlers, but here, as in other parts of the world at that period, the difficulties in the way of successful culture were extremely great, and as early as 1806 the crop

Australian Lucerne.—Typical plant of Australian Lucerne, showing erect growth, strong stems, freedom from excess branching, and vigorous rooting system.
—Photo: W. J. Spafford.

was referred to in a report by Governor King, wherein he stated: "Lucerne grows extremely well, surviving at least three cuttings a year, but as it requires so much care and attention to keep it in tilth, and will not admit of being fed off, but few cultivate it."

At first, the progress the crop made was slow, but there has been a progressive advancement in the area seeded to lucerne, and in the last decade this has been really rapid, and it is inevitable that it will become increasingly popular as time goes on, in this State.

Description of Plant.

Lucerne (*Medicago sativa*) is a perennial plant belonging to the family of *Leguminosae*, of which it is probably the best known and most valuable member. The plant is either covered more or less with soft hairs, or is smooth. It grows from 1 ft. to 3 ft. in height, producing fairly upright stems, with many branches and much foliage. The stem originates from the crown at the summit of the tap-root, which is situated above or at the surface of the ground. The leaves, which are arranged alternately on the stems, consist of three leaflets, which in all types are wedge-shaped, but vary considerably, some being relatively long and narrow, whilst in other varieties they are short and rounded. All leaflets are toothed at the summit. The flowers, which in different varieties may be any shade of violet, from very pale to a deep reddish purple, are typically pea-like in shape, though much smaller, and are arranged in loose clusters at the summit of each branch. There are from two to six kidney-shaped seeds of a yellowish green colour in each pod, and they are about ⅛ inch in length, the pods being spirally twisted in two to four loose coils, open through the centre. It is a deep-rooting, remarkably long-lived and prolific perennial. Under the best conditions it may be cut many times a year, and year after year. It has been stated that there are lucerne fields in Mexico over 200 years old, and there are in France fields which are known to have

Lucerne Crop.—Showing stand of typical Australian Lucerne.

—Photo: W. J. Spafford.

been in production for over a century. There is no reason to believe that it will not be equally long-lived in Australia, if established on suitable soils, efficiently manured and given reasonable attention.

The tap-roots of the lucerne plants penetrate readily to 10 ft.-20 ft., and have been traced to much greater depths. Lucerne roots have been found 30 ft. below the surface of the alluvial flats of the Hunter River. Coburn records a case where the roots were found penetrating through crevices in the roof of a tunnel 129 ft. below the surface of the lucerne field. This extraordinary growth of the roots of a plant which normally does not exceed 3 ft.-4 ft. in height, shows that there are often differences between the habits of lucerne and other cultivated plants, and this points to the advisability of giving careful consideration to the soil conditions before attempting lucerne cultivation. It will go down to food and water if it can, and it is the farmer's business to see that it can.

It can be stated that lucerne is one of the hardiest of the cultivated crops. Where dry and hot conditions prevail it will produce more growth than any other known perennial plant. Except at the time of seed germination, lucerne does not require much moisture near the surface, and flourishes with sunshine in hot summer temperatures. For most prolific growth, lucerne requires a well-drained deep soil, which is not acid and contains plenty of moisture, either supplied from underground, or supplemented by irrigation, ample phosphatic fertilizers, and thorough cultivation during the life of the crop.

Climate.

Lucerne loves heat and makes its maximum growth in the spring and summer. It is at its best with plentiful supplies of water in combination with heat. Under such conditions, which in this State usually involve irrigation, it is remarkably prolific, successive cuttings of luxuriant forage being obtained at intervals of five to six weeks with an aggregate yield per acre of 20 to 25 tons of green fodder, or if made into hay of 6 to 8 tons. Owing to its deep-rooting system, it is well able also to withstand extremes of temperature. It is well adapted to withstand summer drought. The most favourable climates, however, are:

1. what has become known as semi-arid,
2. sub-tropical,

and in these climates, when sufficient water is available and good management is practised, lucerne gives its maximum return. Grown experimentally without irrigation at the Chapman and Merredin Research Stations, it has proved that it will live for several seasons through the dry summer, remaining dormant during the dry portion of the year awaiting summer showers or the winter rains to spring into activity.

It is believed that there is no part of the agricultural area in which this plant cannot be made to serve some useful purpose. For maximum returns for fodder or hay, irrigation will probably be necessary in most districts, with the exception however, of our lower south-west. In the dry areas, however, sufficient information is available to indicate that it is likely to prove useful for grazing.

Soil.

Except under adverse conditions, lucerne is not particular as to soil. With suitable treatment it will grow on almost all classes from nearly pure clay to light, sandy soils. At one time it was thought that it would only grow on rich, deep, alluvial types, but experience has shown that there is hardly any kind of soil on which it will not grow providing it is not acid or water-logged. The most

favourable one is a rich, somewhat sandy loam, warm and friable. The highest yields are obtained with the least trouble on the very best alluvial soils, found on creek and river banks, well supplied with plant food, and with free water from 6 to 20 feet below the surface. At one time, heavy clays were considered unsuitable, but cases are recorded where excellent crops have been raised on soils of this character. However, more care is required in preparing the seed-bed than on friable loams.

While lucerne can utilise enormous quantities of water during the growing period, it is killed by stagnant water lying upon it. A case is known, however, where the flood waters from the Hawkesbury River remained on a lucerne paddock for 8 days during the winter when the roots were partially dormant, and they did not do any permanent injury. In this instance, the deposits left around the plants were removed as soon as the water receded. Under Western Australian conditions many types of land are used for the cultivation of lucerne, but generally all farmers realise the value of alluvial soils and loams, preferably those which are fairly well supplied with lime. Lucerne has been known to send its roots 10 to 20 feet below the surface on dry lands. Under certain favourable conditions, the underground water may supply all the needs of the crop. It must be remembered that once the roots have penetrated to the water table, a sudden rise in the water table may seriously affect the ultimate stand of the crop.

Good drainage is the essential requirement of the lucerne plant, and waterlogged soils are useless for the crop. In naturally wet land, or land made so by the incorrect use of irrigation water, lucerne is very apt to take on a sickly yellow appearance. Under these conditions, weeds will become a severe competitor with the lucerne crop. It is well to remember that lucerne will not stand wet feet. Consequently, if the soil is not naturally drained to a depth of several feet, action must be taken to bring about this condition before the lucerne is planted.

Preparation of the Seed-bed.

Lucerne likes a compact, well prepared seed-bed with just a little loose soil on the top. Although lucerne, when established, is one of the hardiest of plants, yet when young it is delicate, and requires favourable conditions for its support. In some of our drier areas it has been found that a cloddy surface seed-bed is advantageous when establishing young lucerne plants, more particularly where spring planting is adopted. Under general conditions, the seed-bed should be warm, mellow and compact, with just a thin layer of loose soil on the top. It is essential that it be compact, in order that the seed may germinate readily and the soil moisture move most freely in all directions to convey the necessary nourishment to the young plantlet. The compact soil in which the seed is deposited should be covered over with a layer of loose soil, thin enough for the small and tender plant to force its way through, so that the evaporation of the moisture brought near the surface by the compaction of the under layers for the use of the roots, will be lessened. Because of these requirements, it is generally advisable to commence the preparation of the land some time before sowing, usually by fallowing and the plowing can then be deep. Except in rare instances the plowing should not be done later than at least six weeks before the seed is to be sown, for if plowed later than this, it is difficult to get the seed-bed into that compact condition which is so essential for the best results in the establishment of this crop. The planting of the seed in a loose seed-bed is a frequent source of failure with a lucerne crop. It is also desirable to have the seed-bed very free from weeds and weed-seeds, as these are a big problem in the establishment, for they will often kill or smother young lucerne seedlings, owing to the slow initial growth of the latter. This

condition is the most frequent cause of failure of young lucerne stands. Where autumn planting is carried out, it is necessary that the land be properly bare fallowed, firstly to assist in controlling weeds, and secondly to assist in controlling such pests as Lucerne Flea and Red Mite. To do this it is essential that no weeds of any kind be permitted to grow. Where fallowing is not adopted it is necessary to plant the lucerne in drills, so that inter-cultivation may be carried out. Prior crops, such as oats, potatoes, etc., are advisable, as these crops assist in controlling weeds and loosening the ground. Where following a crop of potatoes, there is the added advantage of the residual fertiliser. Following on a cleaning crop the land should be worked down with harrows and disk cultivators. Before planting the seed, final preparation is necessary. This would consist of a further harrowing following up rolling to make a fine, firm seed-bed.

Time of Planting.

Lucerne can be seeded either in the autumn or in the spring, but the time of sowing will vary with a number of conditions. In warm and particularly the dry districts of Western Australia, autumn sowing, i.e., March or April, is likely to give the best results, provided the weeds and Red Mite can be controlled. Rain usually falls then and the ground is warm to ensure good germination of the seed, and a vigorous growth of the plants. During the winter, plants have opportunities to make good root growth, so that it becomes strong enough to stand the hot weather of summer. On the other hand, in cool districts with a liberal rainfall, or where weed growth, Red Mite and Lucerne Flea are troublesome, spring sowing is advisable. Where spring planting is practised, the ground should be fallowed in the autumn or winter, to assist in combating pests and weeds. If the areas are to be irrigated, the seed can be sown whenever convenient to the farmer. Generally the best results would be obtained from autumn planting.

Seed.

It is well known that a good seed-bed is essential for success, but the time and trouble expended on the preparation of it may be wasted by the use of poor seed, as good stands cannot be expected from such. Only seeds that are plump, bright yellow in colour with absence of hard dark brown, shrivelled or immature, and free from weeds should be used. Old seed is usually dull and darker in colour, as the brightness soon fades with age. In immature seed, it is generally greener in colour, even when not badly shrivelled. Germination tests of the seed prior to sowing are advisable, but still may not give a true index when sown into the soil.

Varieties.

There are several kinds of lucerne. These are, however, types rather than varieties, and are mainly of localised character and usually distinguished by the name of the country in which they have been grown, e.g., Peruvian, Turkestan, Arabian, African, etc. Many of these have been tried in Australia, including trials at the Chapman Research Station, W.A. The results obtained there are in accord with those obtained in the Eastern States, and are to the effect that none is as suitable for, or as prolific under Australian conditions, as the Australian type, which has been evolved as the result of the survival of the fittest. This early experience has been confirmed by experiments carried out by Dr. Dunne, the Merchants' Research Officer, Muresk Agricultural College. In the June issue of this Journal, 1935, he reported:—

"In 1932, a number of varieties of lucerne were collected and planted with a view to making preliminary comparisons of drought resistance and growth. The

following varieties of *Medicago sativa* were included, viz., Hunter River, Marlborough, Tamworth, Mudgee, Tagerim, South African, Provence, Italian, English, Chinese, Mongolian, Poitu, Spanish, Smooth Peruvian, Hairy Peruvian, Montana, Dakota, Kansas, Ladak, Utah, Hardigan, Arizona Common, California Common, North Californian and Grimm. Hardy lucerne, a variety of *Medicago media*, was also included.

"The experiment was carried out on a sandy loam soil which had been timbered with jam. The average rainfall at Muresk is 17 to 18 inches per annum, most of which falls during the winter season. The first reliable cropping rains usually occur about the beginning of May and the last useful rains during October. Occasional good falls are sometimes recorded earlier in the autumn.

"No supply of moisture was available for summer growth. The plants were not irrigated, and there was no subsoil seepage.

"It will be appreciated that, under these conditions, the most desirable varieties would be those which, in addition to being able to survive the dry summer months, were capable of making a reasonable amount of growth during the cooler months of the year. Varieties able to grow only under warm conditions would be unsatisfactory owing to the fact that during most of the warm weather no moisture would be available.

"Early rains were received in 1932 and planting was possible on 7th April. The rows were about half a chain in length and were spaced about 18 inches apart. Good germination was secured and all varieties made a satisfactory beginning. Superphosphate was applied at the time of seeding and thereafter each autumn and spring.

"It was found possible to cut the varieties three times each year, about the end of June and of September and during November. In a good season four cuts could be secured. Cutting was done when the most forward varieties contained a fair proportion of the plants in flower. At this stage the best varieties were 2 ft. 6in. to 3 ft. in height. The late September cutting was usually the best. The growth of the better varieties was considered very satisfactory for the conditions.

"The best two varieties as shown by the trial were North Californian and Hunter River. The former made a somewhat quicker recovery after cutting and made a little better growth during the colder months. However, the stems of this variety, which tended to become quite hard about the time of the November cutting, appeared to be normally rather coarse. This undesirable feature may possibly have been overcome by a heavier seeding. Hunter River made quite satisfactory growth throughout the season and had thinner stems and more leaf than North Californian.

"Hairy Peruvian, which made satisfactory growth, appeared to be the next best variety. In stem and leaf it was about intermediate between Hunter River and North Californian.

"There was little difference in value observed between a number of varieties comprising Marlborough, Mudgee, Tamworth, South African, Smooth Peruvian and California Common. All appeared to be inferior to those above mentioned.

"Practically no winter growth was made by varieties which have been selected for varying degrees of winter hardiness and ability to withstand extremely cold conditions. Any growth made was practically confined to October and November. These included the American varieties, Grimm, Ladak, Utah, Hardigan, Kansas, and Hardy, as well as Tagerim, Chinese, and Mongolian.

"All varieties under test were quite drought resistant and were able to keep alive over the dry summer.

"The preliminary trials indicate that, under conditions similar to those obtaining at Mursek, it is best to continue with Hunter River lucerne, which has already given satisfaction under a variety of conditions in Australia. More extensive trials may show additional merit in North Californian or Hairy Peruvian for these conditions, but until these are carried out no departure from the Hunter River variety can be recommended.

"Owing to the presence of other trials in the same area it was only possible to graze with sheep on one occasion (June, 1934). It is possible that the results may have been somewhat modified were the plants grazed instead of cut, but it is believed that in the main the conclusions would be similar."

At the Denmark Research Station similar results to those at Muresk were obtained, and in the drier districts it is now recommended that in addition to Hunter River lucerne, varieties known as North Californian and Hairy Peruvian can be sown.

During recent years advertisements have appeared in the agricultural press claiming very distinct advantages of certain strains of lucerne, the roots of which are offered for sale. These roots are said to be the progeny of a selected surface rooting plant, and it is claimed that planting them will result in the establishment of a superior type of lucerne. As the result of very careful inquiries growers cannot be advised to purchase these roots, as there is no evidence to show that they have any advantage over the best strains of the Australian variety. Observations in any field of lucerne will clearly reveal that many plants differ considerably in their vegetative characteristics, such as leafiness, rapidity of growth, drought resistance, and, in Western Australia, resistance to such pests as the Lucerne Flea (*Smynthuris viridis*) and Red Mite (*Halotydeus destructor*). Because of this, growers are advised to accept with caution the claim sometimes made for "new" varieties, especially those which are offered for distribution by roots.

Good seed of the right kind is essential, and therefore the grower should see that he obtains it by using Australian-grown seed, most of which now comes from New South Wales. Realising the superiority of seed produced in the Commonwealth, the Federal Government now insists that all imported seed shall be stained pink, so as to make it readily distinguishable from the local seed, which in colour ranges from green to purple. Most of the seed produced in the Commonwealth is grown in New South Wales in the Hunter River, Tamworth and Mudgee districts. Seedsmen are required to guarantee the germination and the maximum percentage of weed seeds and impurities in the samples offered. A good sample should have a germination of about 80 per cent., and should not contain by weight more than 1 per cent. of weed seeds and of impurities. The sale of lucerne containing dodder and other noxious weed seeds is absolutely prohibited.

Dodder.

Dodder (Cuscuta spp) is a parasitic plant vine which grows from seed. It is probably one of the most serious lucerne pests the grower has to face. The seed germinates in the soil and retains its connection with this until it comes into contact with the stem of the lucerne plant. It then severs its direct connection with the soil and lives upon the juices of its host, the lucerne plant, until it ripens its seed or has killed the host. Once started dodder continues to grow and spread by means of its tendrils, which grow from one plant and catch other adjacent ones. The plants first attacked begin to die and the pest spreads out in all directions.

Lucerne and Dodder.

The tiny seed of this pest is sometimes found in an admixture of lucerne seed, and because of this disastrous effect upon the crop, precautions should be taken to prevent its being introduced with the lucerne seed which is being sown. Because of the difference in their relative sizes, some dodder seed can be separated from lucerne seed by suitable cleaning machinery, but, because of the vital importance of not introducing dodder, only lucerne seed which has been harvested from crops known to be free from dodder should be used.

It may be, however, that despite the precautions taken, dodder has established itself. Every effort should be made to eradicate it. If very generally established, probably the best way of dealing with this pest will be to plough up the paddock and grow other crops upon it for a number of years until all the dodder seeds have germinated and the plants arising therefrom have been killed. For dealing with isolated patches the usual method recommended is to mow or hoe them, cover them with straw, and burn the dried material. Close and repeated grazing for some time may also prove effective, as the animals are likely to eat the dodder quite close to the ground and prevent it forming seed. Mowing has proved ineffective owing to the fact that little tendrils of the dodder plant are left on the lucerne stems near the ground and below the cut surface of the lucerne.

Rate of Seeding.

The amount of seed to sow per acre depends on the quality of the seed, the method of sowing, the nature of the soil, the firmness of the seed-bed, the district in which it is planted and for what purpose the crop is intended. Consequently, no general recommendation can be made. For hay-making purposes, the amount sown by farmers ranges from six to 20 lbs. per acre. If, however, it is intended that the crop shall be grazed, the quantity sown is much less and ranges from two to eight lbs. per acre. In some of the lucerne growing districts of the Eastern States where lucerne hay is the staple crop, the practice is to sow about 25 lbs. of seed per acre, and growers have been known to state that they would prefer to sow 30 rather than 20 lbs. per acre. This attitude is due to a realisation of the fact that many causes operate against plants succeeding and prevent more than a small percentage of the seed from producing healthy established plants; the young seedlings are tender and have difficulty in reaching the

surface after germination. During the process of covering many of the seeds sink too deeply into the soil, whilst many remain quite near or on the surface and fail owing to insufficiency of moisture. Further, whilst the lucerne crop is being established a process of elimination occurs, weeds rob the soil of the fertility, use up moisture, and compete with the lucerne for light. This makes the plants thin and spindly and generally saps their vigour, and in consequence it is only the strongest plants which survive.

It is considered that, when established, a stand of some 500,000 plants per acre is ample. Seeing that 1lb. of lucerne seed contains about 220,000 seeds the use of from 2 to 3 lbs. of good seed per acre would meet these requirements, and though it is recognised that a farmer should not run the risk of a thin crop as the result of being niggardly with the seed, it is considered that the use of 6 lbs. of good seed on well prepared land allows for the many contingencies referred to, and that to use more than 12 lbs. is unduly extravagant.

Generally speaking, in the South-West, if the seed is to be sown in drills, 6 to 8 lbs. per acre will be found satisfactory, but if broadcasted, 10 to 12 lbs. would be required for good results. Under irrigated conditions, 15 to 20 lbs. of seed per acre is recommended. In the wheatbelt a rate of 2 to 6 lbs. per acre should be used when sown in drills. All the rates of seeding mentioned for different conditions depend upon obtaining good seed and having good soil conditions before sowing, otherwise the rate of seeding per acre must be increased.

Method of Sowing.

Except on loose, drifting sands lucerne need not be sown with a nurse crop. There is a general agreement amongst experienced lucerne growers that if lucerne succeeds with a nurse crop it is in spite of the additional drain upon the soil moisture instead of by reason of it. This is particularly applicable to dry climates, for when there is only a limited supply of moisture available, all this will be required to germinate the seed and give the young plant a vigorous start in life.

The seed is usually broadcasted and should be sown near the surface. The seed may be broadcasted either by hand, by a hand broadcasting machine of the "Cahoon" or similar type, or through the grass seeding attachment of the ordinary grain and fertiliser drill. An even distribution of seed is desirable; it is not easy to obtain this by broadcasting with such small quantities of small seed. When necessary to sow by hand it is convenient to follow behind a roller or harrow, so as to have a clearly defined area on which to sow. The small quantity of seed used is dealt with by using the finger and thumb instead of the whole hand for picking up and spreading the seed; and sometimes to facilitate the work and ensure more even distribution the seed is mixed with dry soil, sawdust or ashes. When the hand machine is used a small quantity of seed can be sown best by turning the handle the opposite way to the usual one. The seed can be sown down the seed box of the grain and fertiliser drill if mixed with some bulky material like bran. It is sometimes mixed with superphosphate and sown through the fertiliser box, but this method is not recommended on account of the probable destructive action of the fertiliser on the vitality of the seed. When sowing the seed through the "shoes" of the grain drill there is some risk that the seed may be planted too deeply, but provided this risk is known it can be guarded against and avoided. When sown down the tubes of the grain drill the seed can be deposited on the surface by removing the tubes from the "shoes" and at the same time a broadcasting effect can be obtained by arranging for the seed to be dropped on to a sloping board fixed with an inclination of about 30 degrees to the ground.

The seed is sometimes sown in drills which are far enough apart to admit of intertillage. This method is believed to be the best for dry districts, and particularly for places where weeds are troublesome, and for small patches. It is further

recommended as the method to be adopted when determining the suitability of new locations for this crop. The results obtained by Mr. A.C.R. Loaring at "Lawnbrook," Bickley, with lucerne in drills 2 ft. 9in. apart, and recorded in the "Agricultural Journal," April, 1924, prove that there is no need to fear lessened yields from the adoption of this method, and it has several distinct advantages. It enables the land between the rows to be kept loose by cultivation, as the result of which loss of soil moisture by evaporation is reduced to a minimum, and the water is conserved for the use of the crop. Another advantage is that the cultivation given to conserve the moisture also destroys weeds, thus preventing the crop from being robbed of the plant food and moisture which the weeds would use for their growth. It has the further advantage that a saving of seed is effected when planting in this way, for, assuming that only 50 per cent. of the plants were obtained from the seed planted, 2 lbs. of seed will provide 15 plants per foot of row if the rows are 3 ft. apart. The seed is covered either by rolling or by harrowing with a light or brush harrow, but it is best covered by the joint operations of both rolling and harrowing. The rolling presses the seed into the soil, and in this way the germination is assisted; it is, however, undesirable to leave the surface compacted and smooth as left by the roller, for this tends to draw the moisture to the surface where it can be evaporated, and in addition a rolled surface crusts readily after a shower. These disadvantages can be overcome by lightly harrowing the rolled surface.

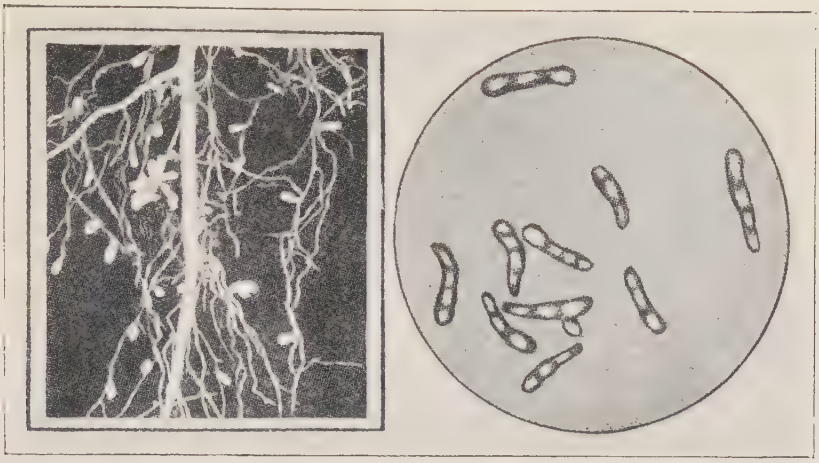
Innoculation.

Under certain conditions lucerne, in common with other legumes, is able to obtain the nitrogen for its requirements from the free nitrogen of the air, which contains about 80 per cent. It is enabled to do this by the aid of certain vegetable organisms or bacteria which derive their sustenance from the nitrogen of the air and the starch of the plant. When acting in this way the presence of these bacteria can be noticed by the appearance of wartlike nodules or tubercules on the roots. The nodular swellings are filled with the micro-organisms and are usually in clusters. Some are as small as a pin's head, others as large as a pea. It was thought at one time that each legume—lucerne, trefoil—had a distinct organism, but now it is believed that legumes of closely related kinds have the same organism and will pass from one kind to another. Thus the bacteria found on "White Sweet Clover" and on "Burr Medic" or "Burr Trefoil" have proved to be also suitable for lucerne, and similarly the one found on the Peas suitable for the broad bean or vetch.

These nitrogen collecting bacteria do not act when there is an abundance of nitrogen in the soil available for the use of the legumes. So to speak, they become lazy.

Seeing that in soils deficient in nitrogen lucerne will be dependent upon the presence of nitrogen-gathering bacteria for its supplies of nitrogen, it follows that if they are not present its development will suffer and will be shown by the pale colour of the foliage. It is important, therefore, to have these organisms in the soil; in fact, lucerne cannot be a complete success without them. Because of the manner in which trefoils flourish throughout this State there is every reason to believe that they will be present naturally throughout the agricultural areas wherever trefoils are found. If, however, they should prove to be absent, they can be introduced, and this process is called inoculation. In the past the most generally adopted method of carrying out the inoculation has been to distribute over the new land intended for lucerne a small quantity of the surface soil from an old established lucerne patch. Soil containing or infected with the required bacteria, at the rate of about

100 to 200 lbs. per acre, is harrowed in with the seed or just before sowing. The danger attendant upon this method is the risk of introducing weed seeds, fungus diseases, or eelworms.



Lucerne Nodules. Lucerne Bacteria.

It was found that these nitrogen-fixing bacteria belonging to the different groups of legumes can be isolated and prepared for distribution in convenient form as "cultures." This scientific discovery was developed to such an extent that "cultures" for the different legumes were used with great success by mixing them with seed before sowing. Recently reports from England indicate that good results have followed the application of these "cultures" to old lucerne fields. In Western Australia excellent results have been, and are being, obtained from the use of "cultures" applied to new land at the time of sowing.

"Cultures" for lucerne and other legumes are now prepared in the laboratory of the Pathological Branch of the Department, and can be obtained by farmers on payment of a small charge.

The effect of lime is to encourage the growth of these bacteria. If the crop is not suffering from excess water, and there are evidences—such as the pale colour of the leaves, or the absence of the nodules on the roots—that the necessary bacteria are not functioning, mild lime at the rate of about one ton to the acre should be applied. On sour and sandy soils a similar dressing of mild lime is also recommended to be applied at least one month before the seed is sown. In addition to stimulating the bacterial activity already referred to, it will also have the effect of correcting the acidity which is so detrimental to success with lucerne.

Manuring.

Lucerne is a heavy feeder. Under suitable conditions twenty tons of green crop may reasonably be expected in a season, and this would contain about 340 lbs. of nitrogen, 60 lbs. phosphoric acid, and 250 lbs. potash. Fortunately, except during the period immediately following germination, this plant is not usually dependent upon the soil for its nitrogen supply. Being a legume it can, when suitable bacteria are present, obtain all its requirements in this connection from the inexhaustible supply contained in the air. But the phosphoric acid and potash must be obtained from that already in the soil or from fertilisers applied to the

soil. On fertile loams it may be assumed that the soil will contain sufficient nitrogen to meet the requirements of the young lucerne plant, and supply its needs until the necessary bacteria are sufficiently plentiful to enable it to secure all its needs in this connection from the air. Because the young plant requires to obtain its early nitrogen requirements from the soil, a small application of nitrogenous manure—sulphate of ammonia, blood, or nitrate of soda—is, however, recommended for sandy soils or others deficient in nitrogen-forming material. Guided by experience in the Eastern States, it is unlikely that, except in sandy soils, potash manuring will be necessary in the early stages, but it is equally likely that manuring with phosphoric acid will be followed by marked beneficial results. An application of from 2 to 3 cwt. of superphosphate per acre is recommended on all soils, even the best.

On loams poor in organic matter it will be advisable to supplement the superphosphate with an application of sulphate of ammonia up to 100 lbs. per acre, so as to meet the requirements of the plant for nitrogen until it is sufficiently established to obtain what it needs from the air. On such soils the fertiliser recommended is therefore:—superphosphate, 3 cwt. per acre; sulphate of ammonia, 1 cwt. per acre. The fertiliser recommended per acre for sandy soils or those deficient in plant food is a complete one consisting of, say:—sulphate of ammonia, 100 lbs.; superphosphate, 400 lbs.; muriate or sulphate of potash, 400 lbs.

Except in soils unusually rich it will be necessary to fertilise the crop annually. Subsequent applications of fertilisers should be governed largely by the returns aimed at or secured. If the soil is not rich enough for its latent fertility to be drawn upon, or if it is desired to replace the plant food removed by the crop, then an application of superphosphate 14 lbs., sulphate or muriate of potash 25 lbs., is recommended for every ton of green lucerne removed.

Well saved stable manure is very suitable for this crop, for in addition to the plant food it contains it also supplies organic matter to the soil, and this improves its mechanical condition. If kept on the surface it acts as a mulch to conserve the moisture, and will be of considerable assistance in preventing the formation of a crust on its surface. The great drawback is the weed seeds it contains for these, unless killed as the result of rotting, are likely to destroy the young lucerne plants. This objection is therefore lessened when the manure has been well rotted and is not serious when applied to well established lucerne beds.

Lime.

On sour and sandy soils a dressing of air slaked lime or ground limestone at the rate of 20 cwt. per acre is recommended as a preliminary dressing to be applied at least one month before the seed is sown. This will have the effect of correcting acidity and stimulating bacterial activity.

Treatment after Sowing.

Even in the best prepared soil, weeds are likely to spring up, for most soils, and particularly old and fertile ones, contain dormant weed seeds, and these germinate with the lucerne seeds and become a menace to its success. It is not possible to cultivate the ground to destroy the weeds which may grow amongst the recently-planted lucerne, for in its young state it is so delicate and with so little roothold that even a harrowing is likely to pull out or damage a considerable number of plants. Lucerne planted in the autumn will rarely be strong enough to be cultivated before the following spring, or that sown in spring before the following autumn. Short of hand-pulling, which is only possible on small areas, the most practical method of controlling weeds in young lucerne is to mow or

graze them. If this latter plan is followed the grazing should be done with small stock and as quickly as possible. The mowing can be commenced when the lucerne plants are four to five inches high, and repeated after a short interval, say, a month. This mowing, though detrimental to weed growth, will not injure the lucerne, but rather will stimulate it. Usually the material from the first mowing will not be worth gathering, and it can therefore be left, with advantage, to mulch the ground. As the object of this mowing is to destroy the weeds it should be undertaken whenever they are plentiful enough to warrant it, irrespective of the condition of the lucerne plants and the necessity for utilising the crop. It is emphasised that mowing does *not* injure but *stimulates* lucerne. When the young plants have a firm roothold, and this can be determined by pulling at them, cultivation of the soil can take place with advantage. Its effect will be to stimulate the crop by letting air into the soil for the benefit of the nitrogen-fixing bacteria, and by conserving the soil moisture. For the first cultivation a light harrow is probably the best implement to use, but as the lucerne gets older much stronger implements, such as the springtooth cultivator or disc harrow can be used. One of the best implements for the purpose on established lucerne—over two years old—is the disc harrow. To one not accustomed to its use it may be thought that it will destroy the lucerne as well as cultivate the soil. This, however, is not so. The discs should not be given too much angle, and they will then split the lucerne crowns and cause them to throw up additional stems.

When the soil of an established lucerne bed becomes hard it can be disced and cross-disced to loosen it up with most beneficial results. There need be no fear that surface cultivation will kill the plants, as they are too deeply rooted to be injured, and the splitting of the crowns is beneficial. Discing and cross-discing is extremely useful should the paddock unfortunately become infested with couch grass. On one occasion the writer had reason to deal with such a paddock, and so badly infested was it that the treatment decided upon was desperate and almost in the nature of a forlorn hope. The ten-acre paddock was double disced twice both ways. The result was astonishing. The lucerne grew with such astonishing vigour as to keep the couch under control when aided by the usual periodical cultivations with the disc, and because of the success which followed this drastic treatment, and which proved that couch grass and weeds could be controlled in established lucerne patches, additional acres of lucerne were planted on that farm.

Feeding Lucerne to Stock.

Lucerne as a food is particularly valuable for the protein it contains. Henry gives the average digestible nutrient in freshly cut lucerne and green fodder maize as:—

	Digestible nutrients per 100 lbs.		
	Protein.	Carbo-hydrates.	Fat.
Green fodder maize ..	1.0	11.6	0.4
Green lucerne	3.9	12.7	0.5

From this it will be seen that green lucerne contains nearly four times as much protein as green maize.

The nutrient protein is the most expensive of our food constituents and is essential for the production of lean meat, wool, milk, and eggs. Young animals, cows in milk, and laying hens require much protein, and because of the large amount of protein which it contains lucerne is very suitable for these animals. It can in many instances profitably take the place of bran or oilcake in the ration,

particularly of milking cows, and which farmers may have to purchase in order to utilise profitably and economically the other products of the farm, or to maintain a continuous milking period.

Comparative analyses of bran and lucerne hay, as given by Henry, are as hereunder:—

	Digestible nutrients per 100 lbs.		
	Protein.	Carbo-hydrates.	Fat.
Lucerne hay	11.0	39.6	1.2
Wheat bran	12.2	39.2	2.7

From the above the similarity between the two is obvious, and it is estimated that in practice 11 lbs. of good lucerne hay is equal to 10 lbs. of bran. In one respect lucerne has a very decided advantage over bran, and that is as a food for pigs. Lucerne is one of the best foods and bran one of the worst for these animals. In the United States of America large numbers of pigs are regularly pastured upon lucerne, and in this connection it is estimated that a vigorous patch of lucerne will carry 15 to 25 pigs per acre, and the pigs will make a gain of about 100 lbs. during the season. Whilst grazing lucerne with pigs it is best to supplement it with an allowance of grain, like maize or wheat. For fattening purposes lucerne will not be found economical if fed alone, for when fed alone all its protein cannot be digested and though the animals increase in weight such increase is principally of bone, blood, and muscle. For fattening animals lucerne requires to be supplemented with foods like maize, wheat, and oats, and other foods richer than lucerne in carbo-hydrates and fat.

Haymaking.

The object of transforming the green material into hay is to get rid of excessive moisture so that the hay when stacked will not heat too much or become mouldy.

Lucerne is much more difficult to make into hay than the cereals. This is because of the very sappy character of the stems, which do not dry as readily as the leaves. These latter are the most nutritious part of the plant, and if they become very dry are likely to fall off the stem during the operations of haymaking. The great object to be achieved therefore is to regulate the drying as far as possible so that the leaves and stems dry simultaneously. The principle underlying the procedure necessary for this is founded upon the fact that the leaves until they are so dry that they cease to function will transpire quite a lot of water and which they will draw from the sappy stems. The methods to be adopted should therefore aim to keep the leaves limp as long as possible, as whilst in this condition they will be drawing sap away from the stems very effectively. In practice the hay is made as far as possible in the windrows or in heaps or "cocks."

Lucerne may be cut at any time for green feed, and it may be accepted as an axiom that it is better at all times to cut early than late. Some farmers commence to cut the crop for hay shortly after the first flowers have appeared, others when the lower leaves begin to change colour. In some instances this latter may happen and the leaves begin to drop and the stems harden before the blooms appear. Unless the weather is very unsuitable for haymaking the mowing should not be delayed or loss may occur in three ways; in the first place the later cut or more mature material is less digestible. After flowering the food constituents are transferred to the upper portions of the plant, the stems harden and become less digestible than when younger; further some of the leaves wither and drop off and this results in loss in weight. Deferred cutting leads to poorer growth in the succeeding crop and may also result in a lessened number of cuttings during the season because of the greater time which the respective cuttings occupy the land.

The following table showing some results obtained at the Utah Experiment Station in a feeding test indicates the loss of nutriment following upon delay in cutting.

Stage of growth and beef lbs. produced per ton of hay-

When 1-10 in bloom—706 lbs.
When in full bloom—562 lbs.
When 1-2 of blooms have fallen—490 lbs.

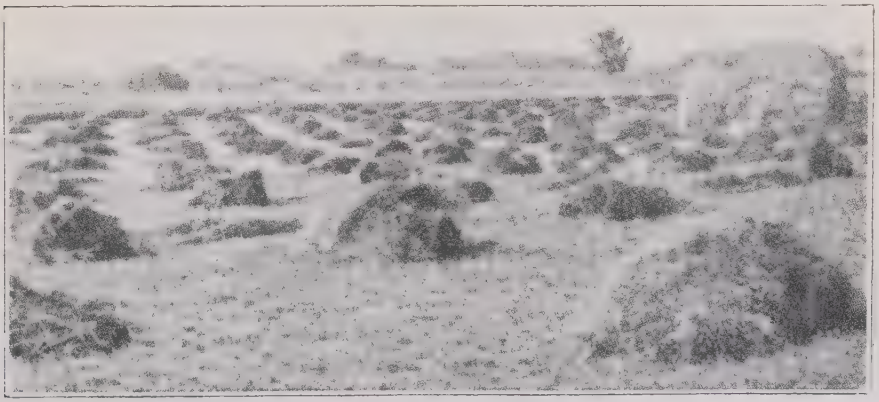
At the Kansas Experiment Station results obtained and the decline in the protein content consequent upon later cutting are as follow:—

Stage of growth and protein content—

When 1-10 in bloom—18.5 per cent. protein.
When 1-2 in bloom—17.2 per cent. protein.
When in full bloom—14.4 per cent. protein.

The first cutting for hay is ready early in spring, and except in the wheat areas, this crop will be difficult to make into hay on account of its sappy nature and the lack of much sun heat at this time. If this cutting can be used for feeding to stock in its green state it is advisable to use it in this way, or failing this, to conserve it as silage. The second and succeeding crops are much more easily converted into hay. In New South Wales when a crop of seed is required the third crop is usually utilised for this purpose, as the flowering at this period is usually more uniform than at others.

Lucerne is usually mown with a scythe, mowing machine, and on occasions with a reaper and binder; it should be cut as close to the ground as is possible without injuring the blade, so as to get the maximum amount of material and to force the new growth from the crown instead of from the joints of the old stems. The usual practice is to start when fine bright weather is expected and as early in the morning as is possible, but not until any dew which may have been deposited has evaporated. It is *not* desirable that the cut material be allowed to remain in the swathe too long, especially if the weather be hot, for extreme heat causes rapid drying of the leaves, and these are likely to fall off during the subsequent operations. If it is allowed to remain just long enough to wilt during bright fine warm weather, this will take only a few hours, whereas with cool moist conditions it may take as many days. After being wilted the material should be raked at once into windrows. If



Lucerne Hay.

the day is a bright sunny one and the mower has been started in the morning, the rake can be started at mid-day, and should catch the mower before night. The next morning the material in the windrows can be placed into heaps or "cocks," and if the weather remains favourable it is probable that the lucerne will be fit to stack the following morning.

Sometimes during hot weather the curing is completed entirely in the windrows, which should be made loose so as to admit the air freely, but in cool damp weather it will be advisable to place the material in "cocks" and allow the curing to finish in them. When dry enough or "cured," the hay is ready to be carted for stacking or baling. This is determined by an examination of the stalks, which need not be dry and brittle, but tough, though without any sap being noticeable when the stems are twisted tightly.

Just before carting, the "cocks" are sometimes turned over to expose the bottom hay for an hour or so to the sun, so as to dry off any hay that may be slightly damp owing to its proximity to the ground. Sometimes in very hot weather the hay becomes too brittle as the day advances, and there is a danger of losing the leaves, and the carting has to be confined to the mornings.

The time occupied from mowing to carting will vary with the season and according to the weather prevailing during the operations. Usually it is under three days, but may be as short as 24 hours. An extreme case was known by Dr. Sutton and is that of Mr. P. Reynolds, "Hobartville," Richmond, who on one occasion stacked his hay in the shed 16 hours after cutting.

Lucerne hay does not shed the rain well, and when stacked in the open should be thatched or protected in some other way from rain. It is best stored in sheds, and should not be stacked on the ground or on a raised straddle of earth; it requires a foundation or straddle of poles to admit air to the bottom of the stack. If stacked on the ground some is sure to spoil.

Grazing.

It is generally recognised that considerable damage can be done to a lucerne stand by indiscriminate grazing, consequently every care must be taken. W. J. Spafford, Deputy Director of Agriculture of the Department of Agriculture, South Australia, in an article on "Lucerne Growing in South Australia," stated:—

"Grazing the lucerne tends to shorten the life of the stand, because it is thinned out much quicker than if stock are never let on it, and if great care is not shown this killing of the plants will be brought about very rapidly.

"To get the best out of the crop without injuring it:—

(1) The crop should be well established before stock of any kind are grazed on it.

(2) The animals should be moved to another field, before they damage the stand.

(3) After resting the field, the plants should be allowed to make growth about a foot high before stock are again put on it.

(4) If possible, the crop should be fed down rapidly, and the stock moved on: this can only be done if the stand is divided into small fields."

Care should be taken when grazing stock on lucerne that they are not let in when it is wet, either by rain or dew, or when they are very hungry. Hoven is likely to be caused by feeding this succulent feed to hungry stock. The danger is greatly increased when the plants are wet. When cattle are being introduced

to this crop after a spell away from it, it is much better that they be well fed first so that they will not be able to consume great quantities, or, if this is not possible, to turn them on for thirty minutes and take them off, letting them on again for a similar period a few hours later. They soon become accustomed to the crop, and will be able to remain in the crop without danger. However, it must be said that grazing, whatever its advantages, materially lessens the life of a stand.

General.

Lucerne has many virtues. These have been summarised in most picturesque language by Geo. L. Clothier, of whom it is stated by Coburn in the "Book of Alfalfa" that he has studied his subject closely in the field, in the feed lot and the laboratory. His summing up is as follows.—

"The cultivation and feeding of alfalfa mark the highest development of our modern agriculture. Alfalfa is one of nature's choicest gifts to man. It is the preserver and the conserver of the homestead. It is peculiarly adapted to a country with a republican government, for it smiles alike on the rich and the poor. It does not fail from old age. It loves the sunshine, converting the sunbeams into gold coin in the pockets of the thrifty husbandman. It is the greatest mortgage lifter yet discovered.

"The alfalfa plant furnishes the protein to construct and repair the brains of statesmen. It builds up the muscles and bones of the war-horse, and gives his rider sinews of iron. Alfalfa makes the hens cackle and the turkeys gobble. It induces the pigs to squeal and grunt with satisfaction. It causes the contented cow to give pailsfull of creamy milk, and the Shorthorn and whitefaced steers to bawl for the feed rack. Alfalfa softens the disposition of the colt and hardens his bones and muscles. It fattens lambs as no other feed, and promotes a wool clip that is a veritable golden fleece. It compels skim-milk calves to make gains of two pounds per day. It helps the farmer to produce pork at a cent and half a pound and beef at two cents.

"Alfafa transforms the upland farm from a sometime waste of gullied clay banks into an undulating meadow fecund with plant food. It drills for water, working 365 days in the year without any recompense from man. The labour it performs in penetrating the subsoil is enormous. No other agricultural plant leaves the soil in such good physical condition as alfalfa. It prospects beneath the surface of the earth and brings her hidden treasure to the light of day. It takes the earth, air, moisture and sunshine, and transmutes them into nourishing feed stuffs and into tints of green and purple, and into nectar and sweet perfumes, alluring the busy bees to visits of reciprocity, whereon they caress the alfalfa blossoms, which, in their turn, pour out secretions of nectar fit for Jupiter to sip. It forms a partnership with the micro-organisms of the earth by which it is enabled to enrich the soil upon which it feeds. It brings gold into the farmer's purse by processes more mysterious than the alchemy of old. The farmer with a fifty-acre meadow of alfalfa will have steady, enjoyable employment from June to October, for as soon as he has finished gathering the hay at one end of the field it will be again ready for the mower at the other. The homes surrounded by fields of alfalfa have an aesthetic advantage unknown to those where the plant is not grown. The alfalfa meadow is clothed with purple and green, and exhales fragrant balmy odours throughout the growing season to be wafted by the breezes into the adjacent farmhouses."

Convenience in Pig Farming.

M. CULLITY, Agricultural Adviser.

The following notes are put forward with the hope that farmers will consider means of reducing the labour required in their pig feeding and management to a minimum. Haphazard methods in this avenue of farming frequently cause farmers to lose interest and to design their system of farming so that pig raising is reduced to the smallest possible scale.

The drudgery which is usually associated with pig feeding is unnecessary, and a little intelligent planning will reduce the time required, make the work more pleasant and allow the pigs to live in a condition more conducive to healthy growth and economical fattening.

Position of Piggery relative to the source of the basal food.

The first consideration that should have the farmer's attention is the relative position of the feeding troughs and the feeding base, that is the separator on a dairy farm and the grain supply on a wheat farm. In the dairying districts it is frequently the case in undulating country that the piggery is situated on higher land than the milking shed. This certainly has an advantage in that the pigs are on high ground and therefore drainage is adequate during the winter months. But undue labour is caused when the milking shed is on a lower level, as all the skim milk has to be carried uphill. This unnecessary labour causes the farmer to avoid this side of farming if at all possible, or at least to that point where pigs are kept solely as a means of using up the surplus skim milk. The pig is then regarded solely as a means of ridding the farm of that surplus rather than a very economical means of converting it into revenue.

In selecting a site for the pig runs, therefore, it is advisable to do so with a view to avoid unnecessary labour. When the piggery is on a lower level than the separator room there does not appear to be any reason why the milk should not be allowed to gravitate to a tank at the pens per medium of an open fluming or pipeline. Criticism may be made against these methods with reference to the possible corrosive action of the milk on the metal of the pipes and also to the difficulty of keeping them clean. Pipelines are in use on a number of farms, and appear to be giving satisfaction. Farmers report little difficulty in keeping these lines clean. The usual method is to flush them with cold water after the skim-milk has gone through and at regular intervals to follow this with hot caustic soda. This of course should then be rinsed from the pipes, preferably using boiling water. It appears to be unnecessary to give a caution against allowing the soda to reach the feeding tank. The provision of a tap at the lower end of the pipe is useful in allowing the pipe to be filled and allowed to soak. Where machine milking is being carried out, and the milk cannot be gravitated the use of a small pump will force the milk to the pens. This pump could be driven during separation and the added cost for this work would be infinitesimal, while the saving in time and labour would be incalculable.

In the case of a wheat farmer a similar saving would be effected if a supply of crushed grain were kept in a feed house as close to the feeding point as possible. This supply would need replenishing at intervals only.

Convenience in feeding may be achieved in those areas where grain is the principal part of the ration by utilising the self feeder. The pigs help themselves when hungry and periodic inspection only is necessary to ensure that ample food is available. (See J. of D.A., W.A., Vol. XIII., No. 4. Pigs—Breeding and Management.)

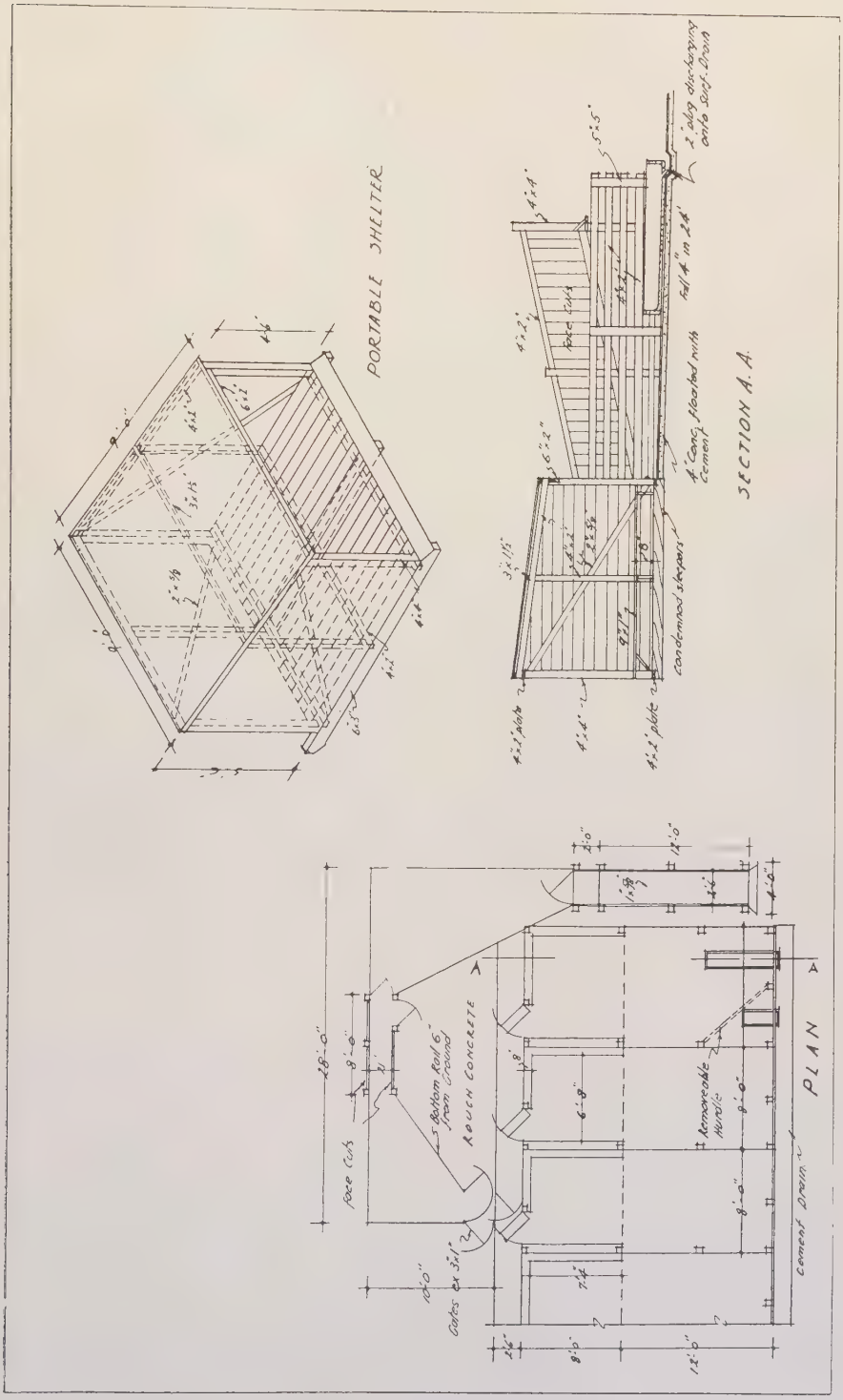


Fig. 1.—Layout of farrowing pens, the detail of the race and plan of the portable shelter.

Position of troughs and the method of feeding.

Having the food at the piggery the next consideration is how to get it into the troughs with the minimum of labour and annoyance and in the cleanest possible manner. A common practice is to have one or two feeding troughs in a sty. The feeder climbs over the fence with a bucket of milk and wages war on the hungry pigs until he can reach the trough and deposit the feed therein. This practice results in considerable splashing of milk, fouling of the man's boots and clothing, fraying of his temper and an undue physical strain.

In order to ensure the greatest possible degree of cleanliness there can be no doubt that no matter what the design of the piggery, the feeding trough should be on a concrete base.

For convenience the trough should be near the fence to facilitate feeding without creating the necessity for the feeder to enter the sty. This can be effected

Fig. 2.
A concrete feeding race with troughs projecting from the stics. (Photo. Miss D. Noon.)

by having the trough at right angles to the line of fence projecting sufficiently through to enable the milk to be poured in. (See Figs. 1 and 2.) The milk then flows along the trough inside the fence. A disadvantage of this method is that it usually causes a struggle amongst the pigs for the position nearest the fence, when the rapid drinker will obtain more milk.

When the trough is placed along the fence line a swinging hurdle (Fig. 3.) may be used to shut the pigs away from the trough until the feed is placed therein. The hurdle is then returned to its normal position and the pigs allowed to feed. This method is useful when feeding either liquid or dry feeds. Another method entails the provision of a metal chute via which the milk can be poured from the outside of the fence.

The possibility of eliminating the carriage of milk from the holding tank at the sties to the troughs by installing a readily dissembled pipeline with cocks over the troughs is being considered by a few farmers.

Whatever system of feeding is adopted, strong advocacy is made of those methods which do not require the feeder to enter the sty. Apart from the circumstances mentioned earlier, it is almost certain that the flesh of those pigs nearing marketing weights will be blemished through the scramble for the bucket and by the man forcing his way through them to the trough.

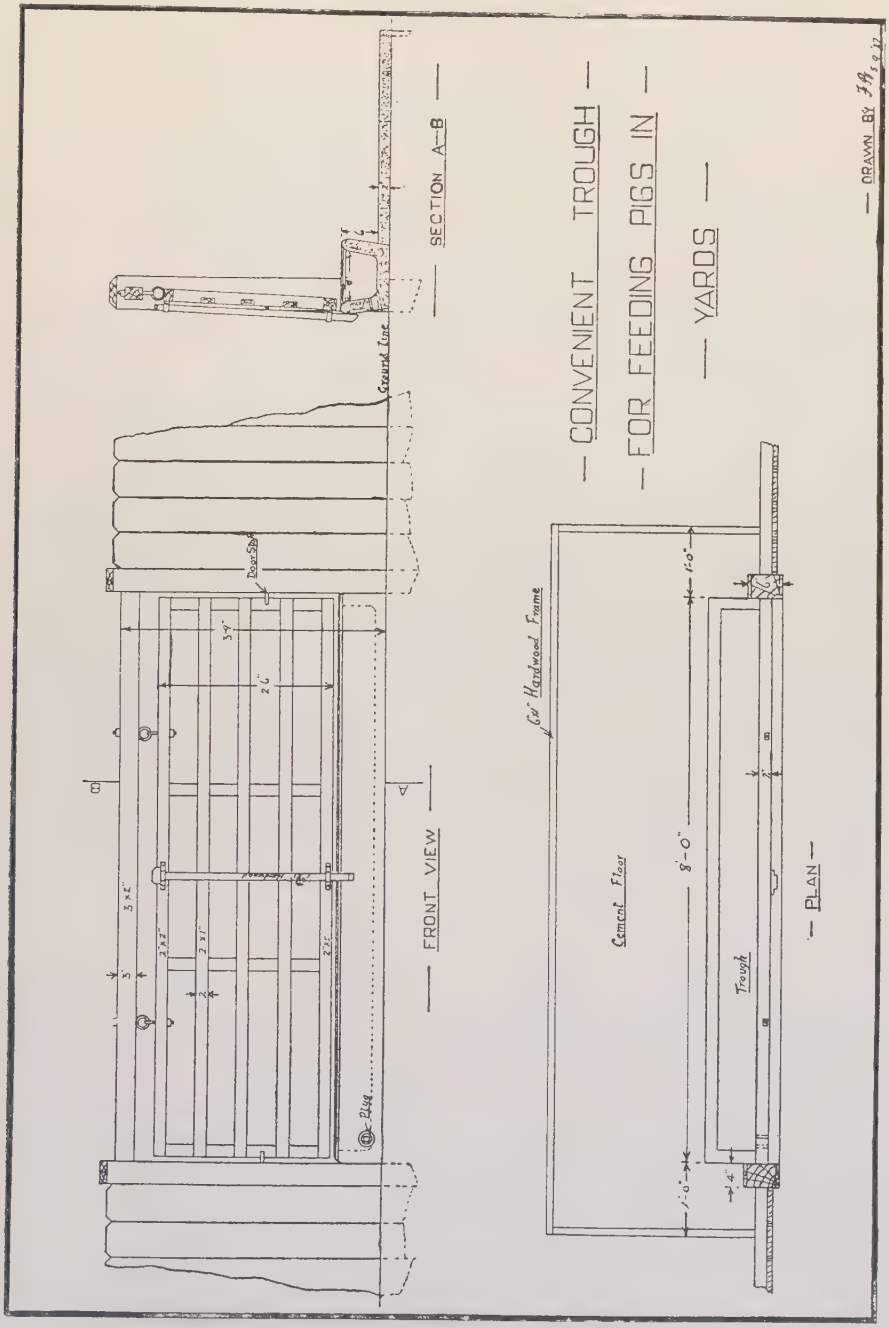


Fig. 3.—Plan of feeding trough showing the swinging hurdle.

Sufficient trough room must be allowed to hold all the food to be given, and it is also necessary that sufficient room be available for all the pigs to feed at once. As a guide it may be suggested that at least one foot length of trough be allowed for each pig. Slats at this distance apart are frequently used to prevent burly animals from forcing weaker ones away. They also have the effect of preventing pigs from getting into and lying in the trough.

Grouping of pigs according to weight.

There are several disadvantages in running too many pigs together. For convenience and at the same time to enable feeding to be carried out according to the stage of growth of the pig, a number of pens and paddocks should be provided. This enables the farmer to segregate his pigs into relatively small groups according to their weights. Where this is not done certain of the stronger pigs will consume more than their proportion of the feed to the detriment of the weaker.* Having the additional accommodation ensures that struggling and fighting among the pigs will be reduced to the smallest possible extent, and gives each pig a reasonable chance of growing under calm conditions.

Creep feeding of litters.

In the case of sows and litters, it is the exception rather than the rule to feed the litter separately from the mother. After about three weeks the young pigs are willing to forage a little for themselves and attempt to feed at the mother's trough. The amount they can consume in competition with her is small, and they incur the additional risk of injury through being nosed out of the way. The provision of a creep is one of the surest methods of rearing a weaner which will be an economical fattener later. The operation of the Manuwatu-Ororu Pig Recording Club in New Zealand demonstrated that creep feeding was responsible for the production of the strongest pigs and these carried their rapidity of growth into their later development. McMeekan and Hammond have since demonstrated that it is advisable to feed the pig during the early months so that it will make its most rapid growth. For bacon pigs they suggest that approximately the first two-thirds of the feeding period should be full fed and that it is then most profitable to reduce the rate of feeding so that the animal will develop to bacon weights without laying on undue fat.†

Cleanliness.

The condition in which the piggery is kept has a very decided effect on the farmer's reaction to the job of pig farming. The degree of cleanliness is frequently bound up with the design of the premises. If this design or layout is good and the floors and pens at least can be kept clean of the mess that is frequently seen, the farmer will not react so quickly to a fall in price, by quitting his breeding animals and letting this sideline lapse. Should the conditions be the reverse, a fall in price is often a heaven-sent excuse to reduce the scope of the operations.

Farrowing Pens.

In Fig. 1 is shown a suggested layout for six farrowing pens which may also be used as fattening pens. Larger feeding pens and paddocks also can be provided. A race system has been designed to facilitate the handling of animals to and from the paddocks to the pens or loading ramp.

* A simple creep is described in the article on Pigs, Breeding and Management by G. K. Baron-Hay, J. D.A., W.A. Vol. XIII, No. 4, and its position in the pen is indicated in Fig. 1.

† It is during this early period that the pigs make their bone and muscle and the continuation of this full feeding as they approach maturity will only lead to surplus fat.

Pasture.

Pasture is strongly advocated as a means of providing part of the ration, the necessary vitamins which can be obtained most cheaply from green material, and also serves as the opportunity of giving the animals exercise. But the means of providing this pasture is often thought to be simply the provision of a small paddock in which there is very soon no pasture. The writer can see no objection to allowing the pigs to run over the dairy pasture as long as precautions are taken to prevent any tendency of the pigs to harm the pasture by rooting. In some close settled localities this is not possible owing to the tendency of pigs to roam, unless pig-proof boundary fences are present. Nose rings are most commonly used for the purpose of preventing rooting, and are quite effective while they remain. But owing to these breaking away, replacement is often necessary. Snout clipping is permanent and removes any tendency of the animal to root, as portion of the cartilaginous matter in the snout is removed and the animal is no longer capable of forcing the snout into the ground.

Improved Berkshire pigs on Kikuyu grass pasture. Good mesh fences are noticeable. (Photo Miss D. Noon.)

Where the use of the dairy pastures is not convenient, the small paddock system is recommended. The number of paddocks that will be required will depend on the number of pigs that one plans to feed. These paddocks will tend to get bare, so provision must be made for resting or cultivating them periodically. For this reason it is advisable to have a number of paddocks which, because they are small, should preferably be long and narrow. This has the double advantage of easy cultivation and the possibility of using temporary cross fences to segregate the pigs on to set portions. These paddocks should be connected to the fattening pens and loading ramp by a laneway.

In Fig. 5 is a layout of paddocks which is adaptable to most conditions other than on very hilly country. This system allows cultivation and rotational grazing, so giving the maximum of food material, and tending at the same time to keep the animals in health by giving them ample exercise.

A diagram of a movable shelter for use in such paddocks is given in Fig. 1.

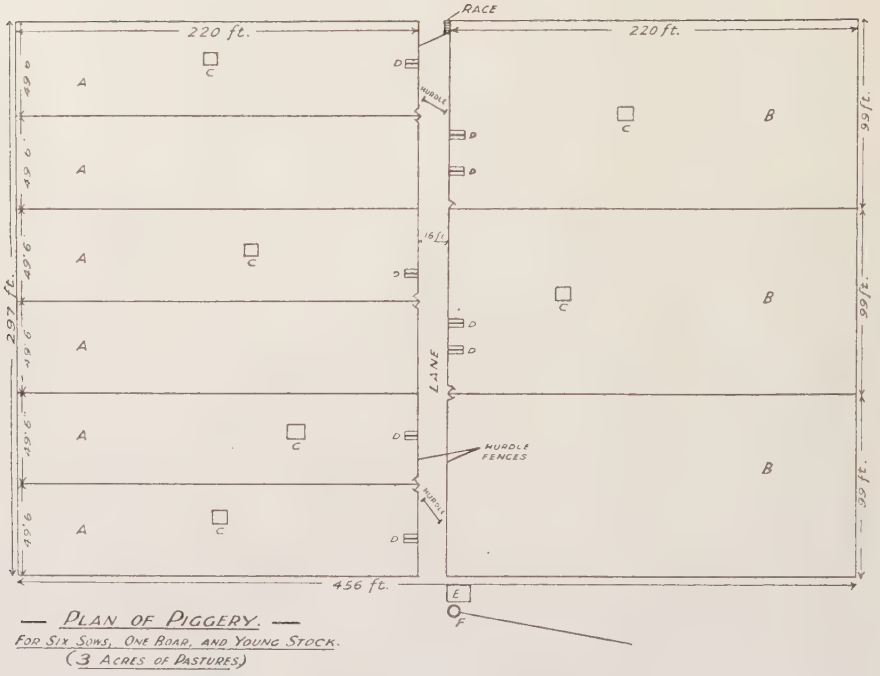


Fig. 5.
Plan of paddo k system.
(With acknowledgments to the Queensland Agricultural Journal, March, 1934.)

Fig. 6.
Electric fencing is useful for temporary fences. Note the difference in the pasture inside and outside the fence.

Loading for Market.

The time eventually arrives when pigs have to be marketed, and this again can cause considerable bother and damage to the pigs through the manner in which they have to be handled.

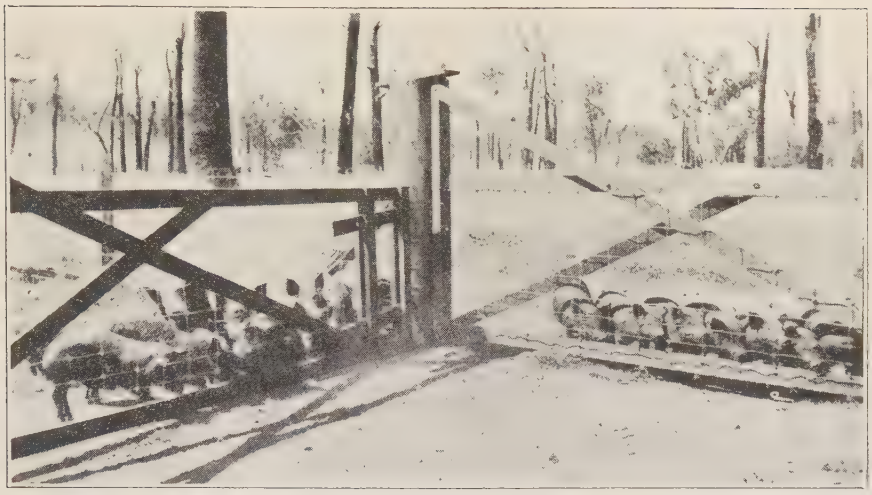


Fig. 7.
Young pigs waiting to go back to their pens from Kikuyu grass paddocks. Note the effective gates.
(Photo. Miss D. Noon.)

Each piggery should be equipped with a small drafting yard and loading ramp. This will permit the loading of pigs with the maximum of ease. It will be noted that a drafting yard is included in the design in Fig. 1.

In handling the marketable pigs through this yard, very great care should be exercised so that the flesh is not bruised. The use of sticks for prodding, kicking, and the use of dogs, should all be decisively discountenanced, as each is the cause of blemishes which cannot be removed. In manhandling any pig, it is suggested that the same care be used. Frequently one sees a pig being dragged along by one hind leg. This can only result in the straining of some muscle with consequent loss.

Some Soil Types Associated with Manganese Deficiency of Cereals in Western Australia.

By

L. J. H. Teakle and A. S. Wild.

Introduction.

Since the recognition by Carne (1927) of "Grey Speck" disease or "White Wilt" of wheat and oats, a condition associated with deficiency of available manganese in the soil, observations have shown this disorder to be of common occurrence, but affecting only limited areas, throughout the wetter portions of the wheat belt south of the main East-West railway line. As described by Wild (1934) the symptoms generally occur in small patches usually a few square yards in area, but seldom more than a few acres in extent, in crops of wheat or oats

grown on high level soils. The disease is most commonly associated with soil types which, in the virgin state, carried mallet (*Eucalyptus astringens*), Manna gum (*Acacia microbotrya*), morrel (*Eucalyptus longicornis*) and mallees (*Eucalyptus spp.*). These soils exhibit characteristic features; they are very rich in ferruginous gravel (laterite), especially in the subsurface layers; the surface sandy layer is of a loose, ashy, or powdery structure; they are slightly acidic in reaction and of low inherent fertility.

On these soils wheat and oats show the characteristic manganese deficiency symptoms. As described by Carne (1927), the symptoms first appear in June or July as stunted yellowish or whitish patches in the crop. Examination of the individual plants shows that while the first and second leaves are generally normal, later leaves characteristically show a spotting somewhere about the centre. These spots are generally light coloured with a pinkish tinge, but later develop grey centres. Usually the spots spread until they cross the leaf, forming an irregular, dead, grey band, while both ends of the leaves are still green. Collapse occurs at the dead area and the upper part of the leaf hangs down, giving the plant a drooping appearance. Subsequently, the balance of the leaf turns yellow and then greyish white as it dies. In addition, the rooting system appears to be defective as the plants are very easily pulled from the soil. If plants survive the winter they frequently recover with the warmer weather of August and September but in cases of acute deficiency the bulk of the plants usually die and the affected area carries only scattered survivors.

Adams (1937) has described the incidence of manganese deficiency of wheat and oats in the Northam district on ferruginous, gravelly soils which originally carried a woodland of wandoo (*Eucalyptus redunca* var. *elata*) and observes that field peas and subterranean clover are less susceptible to the disease. Stewart and Teakle (1939) noted improvement in growth of wheat on patches of ferruginous, gravelly soil at Wagin where manganese sulphate was applied with superphosphate. Similar symptoms are commonly observed in patches in oat crops in the wetter South-Western districts.

However, Teakle, Thomas and Hoare (1933) have shown that the wheat belt and South-Western soils generally show no response to manganese dressings, so that acute manganese deficiency appears to be restricted to certain soil types of relatively limited extent.

Soil Survey of a Farm affected by acute Manganese Deficiency.

a. *Cropping History.*

In the course of advisory work by one of us (A.S.W.) in the wheat districts east of Wagin, a visit was paid early in 1938 to a property which had been cleared and cropped over a period of about 25 years and on which there had been many partial or complete crop failures. Field tests involving the use of manganese sulphate and conducted over a period of two years proved the value of this amendment; satisfactory crops could be produced on the affected soil types when manganese sulphate, at the rate of about 14 lbs. per acre, was applied mixed with the superphosphate. Figure 1 shows the effect in 1939 of withholding manganese on the growth of wheat on manganese deficient soil types on this farm. In this instance the soil type concerned is the Tinkurrin gravelly sand which is described below. Without manganese, the wheat germinated normally and grew satisfactorily for a few weeks. As the season progressed, however, the plants began to look drooping and unthrifty, exhibiting the usual symptoms of man-

ganese deficiency and, in the course of time, a large proportion died. Scattered plants produced heads but grain formation was typically scanty. Where manganese had been applied the crop grew normally and produced a satisfactory yield of grain for the soil type involved—about 15 bushels of wheat per acre. Observations in 1938 indicated that the application of sulphate of ammonia would prevent the development of symptoms of "Grey Speck" disease in wheat on the same soil type on this property. It had previously been shown by Carne (1927) that sulphate of ammonia is beneficial under these conditions, but it is not considered that the effect of this treatment indicates that the disease is not due to a deficiency of available manganese.

Figure 1.—Photo taken on September 14th, 1939, of a strip showing the failure of wheat to make satisfactory growth where manganese sulphate had not been used on the Tinkurrin gravelly sand. As the season advanced the bulk of the surviving wheat plants died on the strip without manganese.

As this farm involves such an area of manganese deficient country, it was thought that it afforded an opportunity for examination of the relationship between the manganese deficient soil types and other soils of the area. Consequently, a soil survey was made in January, 1940, and it is the purpose of this paper to record the observations made.

b. *The Soils and Parent Materials.*

The farm examined covers 1,000 acres of undulating country ranging from high level mallee and scrub plain types to normal salmon gum and morrel soils along the creeks. A clearer understanding of the relationships of the soils can be obtained if the area is regarded as portion of an eroded plateau. The plateau is capped by an horizon of sand and laterite (ferruginous gravels and quartz

gravels coated with ferruginous materials) but where erosion has occurred in the course of the dissection of the plateau, this capping has been removed, or broken up and redistributed. Where removal has been complete the country rock of granite or gneiss is exposed. The upper portion of the country rock exposed by the removal of the laterite capping appears to be a highly kaolinised horizon of weathering. This is often characterised by a considerable amount of quartz grit.

Where the gravelly and sandy materials remain, the soils are poor in fertility and usually carry either a scrub or mallee type of vegetation. These soils may be sandy or gravelly and certain types exhibit acute manganese deficiency of cereals. The Tinkurrin gravelly sand is a good example of one of these types.

Where the gravelly materials have been removed the soils generally range in colour from light grey to grey brown and exhibit the typical features of the grey and brown solonised soils of the so-called "mallee" zone (Teakle 1938).

Mineralogical examination kindly carried out by Dr. Dorothy Carroll of the University of Western Australia, indicates that each soil series is derived from slightly different types of gneiss. The presence of hornblende in Type 1A suggests that it is derived from a hornblende gneiss. The Kukerin sandy loam and Tinkurrin gravelly sand types appear to have been derived from gneisses which contain very little hornblende. In all types the clay minerals of the subsoils appear to be of the kaolinite group. The heavy mineral assemblage is indicated by the following data showing the approximate proportion* of the chief constituents and the relative abundance of other minerals of the heavy residue.

Sample No.	3090	3111	3069	3082
Series	1A	Kukerin	Tinkurrin	Tinkurrin
Heavy mineral—				
magnetite	60–70%	25–50%	25–50%	25–50%
ilmenite	up to 25%	up to 25%	up to 25%	up to 25%
zircon	up to 25%	up to 25%	up to 25%	up to 25%
leucoxene	plentiful	plentiful	plentiful	plentiful
amphibole	plentiful	scarce	scarce	scarce
rutile	scarce	fair	fair	scarce
tourmaline	scarce	*nil*	scarce	scarce
garnet	fair	scarce	*nil*	fair
sphene	*nil*	fair	fair	fair
corundum	*nil*	*nil*	scarce	*nil*
epidote	fair	*nil*	*nil*	scarce
monazite	scarce	*nil*	*nil*	*nil*
sillimanite	scarce	*nil*	scarce	*nil*

* The percentages indicate the range observed for the one sample in different fields under the microscope.

In the course of the soil survey seven groups of soils were recognised on the basis of soil profile features. These groups have been subdivided into a number of soil types which will be described below. Figure 2 shows the distribution of the main soil groups on the farm surveyed.

Group 1—245 acres.

Salmon gum (*Eucalyptus salmonophloia*), morrel, York gum (*Eucalyptus foecunda* var. *loxophleba*) and mallee vegetation associations on soils typical of the mallee zone and largely confined to the lower portions of the area where the parent material appears to be hornblende gneiss.

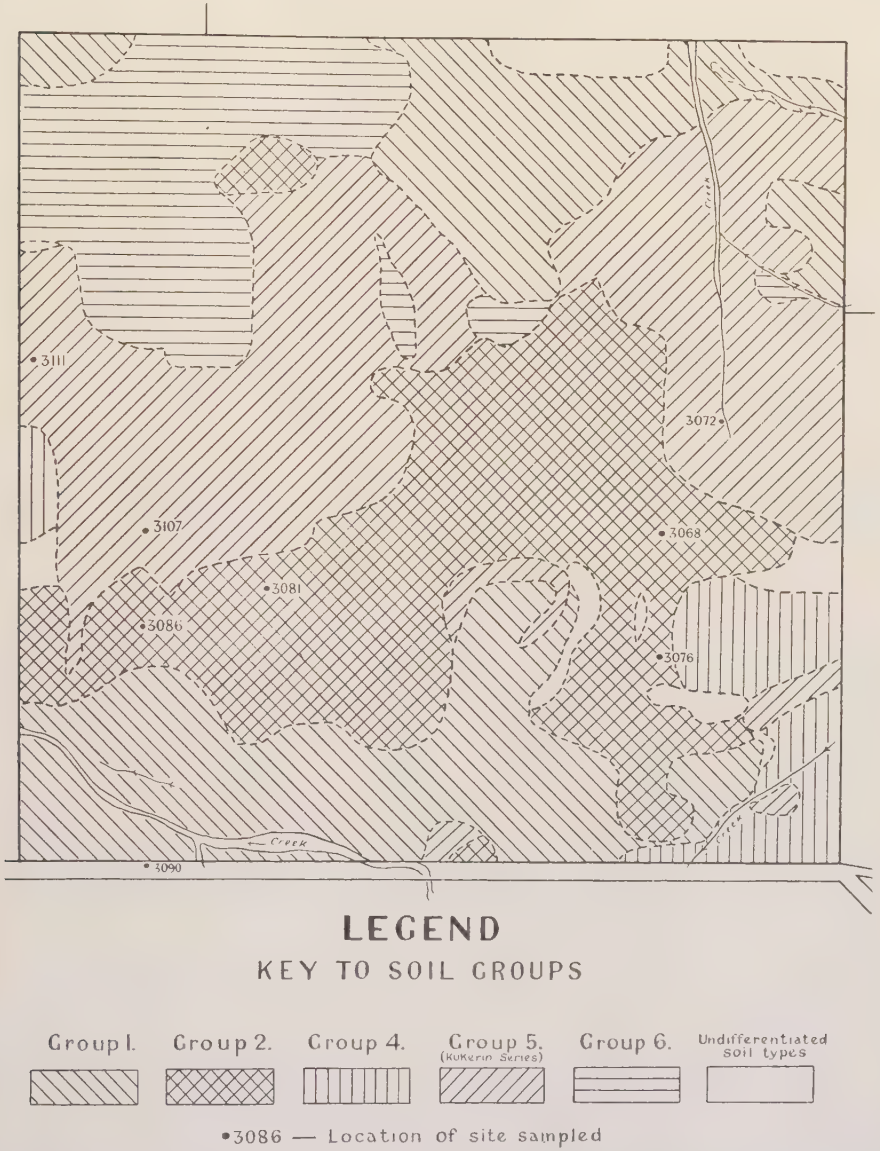


Figure 2.—Sketch map showing the occurrence of the main soil groups recognised in the course of the soil survey. The cross hatched area represents Group 2 which is generally deficient in available manganese.

Type 1*A*.

The typical features of the profile of this type are given in Table 1.

At the site sampled the vegetation included salmon gum, centipede bush (*Templetonia sulcata*), forest daisy (*Olearia Muelleri*), needle bush (*Daviesia aphylla*), *Acacia erinacea*, broom bush (*Melaleuca uncinata*), *Danthonia*, *Grevillea* and *Restionaceae*.

TABLE 1.

PROPERTIES OF A SOIL REPRESENTING TYPE 1A.

This site represents virgin conditions.

Serial No.	Depth.	Gravel.*	pH.‡	Salt (NaCl).	Description.
	inches.	%		%	
3090	0—3	2·6	5·9	·03	brownish grey loamy sand.
3091	3—10	*Nil*	7·9	·07	cementy layer to yellow brown sandy clay.
3092	10—18	12·7†	8·6	·16	yellow brown sandy clay with calcareous nodules.

* Per cent. of the fine earth plus gravel. † Largely calcareous nodular material.
‡ pH of 1 : 5 soil : water suspension by quinhydrone method.

Type 1B.

This soil is similar to type 1A but the profile shows 6-12 inches of sand on the surface and a subsoil slightly lighter in texture. Lime accumulation occurs at greater depths.

Type 1C.

Brown to greyish brown gravelly sandy soil with a brown sandy clay subsoil. The surface sand is less than six inches deep. Patches of red brown gravelly soils may occur in this type.

Type 1D.

Type 1D is similar to type 1C but has a surface of 6-12 inches of gravelly sand.

From the cropping point of view the soils of Group 1 have been the main producers of wheat and oats since the land on this farm was first worked in 1913.

Group 2.—251 acres.

Soils of the upper sandy and gravelly horizon which show more or less acute manganese deficiency.

The surface soil in these types is sand, usually more or less gravelly, and is typically of an ashy, or powdery structure immedately below the surface. The subsurface generally consists of loose gravelly matter mixed with loose sand, and the subsoil is a sandy clay. While the surface sandy and gravelly layers are typically slightly acid in reaction, the subsoil, where clay accumulation is noticed, is generally alkaline. In some instances small amounts of calcium carbonate occur in the subsoil. The occurrence of calcium carbonate in the subsoils of typical soils on lateritic material is very unusual. In this case it is possible that it may be due to the thinness of the gravelly horizon and the nature of the parent materials. On the other hand, this soil type is known to carry mallees in the virgin condition so that the calcium carbonate accumulation may be due to the effect of a mallee vegetation association growing on these particular sites. The writers know of no instances of such calcium carbonate accumulation under heath associations, but it is well recognised that soils carrying mallee characteristically show accumulation of calcium carbonate in the subsoil. Unfortunately this farm had been cleared and cultivated for many years and evidence of the original vegetation on these sites was not obtainable.

This group has been divided into four types of which one, covering the largest area, and typical of manganese deficient areas in many other places, has been given a series name and is called the Tinkurrin gravelly sand. The other soil types of the group are similar generally, but exhibit differences sufficient to warrant their recognition as separate soil types.

The vegetation of this group in the virgin state includes mallees (*Eucalyptus dumosa* and spp.), morrel, mallet (*E. astringens*), manna gum, *Hakea* spp., etc.

The Tinkurrin* gravelly sand.

Details of typical profiles of the Tinkurrin gravelly sand are given in Table 2 and need not be repeated in the text. It will be noticed that this type is characterised by a very heavy concentration of ferruginous gravel and that the surface soils are slightly acidic in reaction.

Type 2A.

The profile of this type consists of a light brown sharp, coarse sand with loose gravel, resting on a yellowish gritty sandy clay loam subsoil. In the virgin state the timber consists of morrel and manna gum. This type is probably transitional between the Tinkurrin gravelly sand and Type 1A or 1B.

Type 2C.

A brown soil type which is evidently very deficient in available manganese. The profile consists of about 5 inches of grey brown powdery gravelly sand on a dark fawnish brown very gravelly sand to a depth of 12 inches. Below this is a layer of brown to yellow brown sandy clay loam extending to 2 feet and resting upon a red and yellow mottled clay with pockets of ferruginous gravel. Further details concerning this type are given in Table 2.

TABLE 2.

PROPERTIES OF SOILS REPRESENTING GROUP 2.

(*Manganese deficient types under cultivation.*)

The gravels consist of ferruginous nodules or quartz coated with ferruginous material.

Serial No.	Depth.	Gravel.*	pH.	Salt (NaCl).	Description.
Tinkurrin gravelly sand—	inches.	%		%	
3068	0—4	22·2	6·4	Trace	brownish grey ashy, powdery gravelly sand.
3069	4—18	70·8	6·3	Trace	greyish yellow very gravelly sand—very loose.
3070	18—36	50·3	6·5	Trace	yellow, yellow brown and reddish mottled very gravelly sandy loam.
3071	36—42	56·0	6·7	Trace	similar but a sandy clay loam.
3081	0—3	14·9	6·3	Trace	brownish grey gravelly, powdery sand.
3082	3—13	51·5	6·5	Trace	pale yellow grey sharp, loose sand and loose round gravel.
3083	13—20	11·3	8·2	·01	similar but a sandy clay loam.
3084†	20—35	10·1	8·4	·02	dark yellow sandy clay loam.
3085†	35—42	12·5	8·3	·02	yellow and grey mottled sandy clay, reddish at 40 inches.

* Well defined soil types have been given series names as a means of more definite characterisation; these names have been taken from the districts in which the types are known to occur.

TABLE 2—*continued.*

PROPERTIES OF SOILS REPRESENTING GROUP 2—*continued.*

(*Manganese deficient types under cultivation.*)

The gravels consist of ferruginous nodules of quartz coated with ferruginous material.

Serial No.	Depth.	Gravel.*	pH.	Salt (NaCl).	Description.
Type 2C—					
3086	0—5	15·7	7·1	Trace	grey brown gravelly sand slightly powdery.
3087	5—13	47·0	7·3	Trace	brown to dark fawnish very gravelly sand.
3088†	13—23	24·2	8·3	·02	brown to yellow brown gravelly sandy clay loam.
3089†	23—29	20·1	8·2	·02	red and yellow gravelly clay.
Type 2D—					
3076	0—4	22·4	6·5	Trace	grey coarse gravelly sand.
3077	4—16	67·8	6·6	Trace	loose rounded gravel and whitish sharp sand.
3078	16—26	64·1	7·0	Trace	grey yellow sandy loam and gravel.
3079	26—36	34·9	7·4	·01	yellow and grey mottled gravelly clay.
3080	36—42	11·8	7·3	·02	C horizon of yellow grey and red gritty, talcy, clay.

* Per cent. of the fine earth plus gravel. † Small amount of calcium carbonate present.

Type 2D.

Type 2D is another transitional type, rather greyer in colour than the others of this group, and appears to be intermediate between the Tinkurrin gravelly sand and representatives of the Kukerin series described below. Details of the profile are given in Table 2 and show that the type resembles other members of this group in being extremely gravelly. It is possible that this type is also deficient in available manganese.

The cropping history of the soils of Group 2 has been one of failure or partial failure of cereals. Either under fallow or wet ploughed conditions, the results have been much the same. The crop has looked poor during the early part of the growing season and has progressively died off during subsequent months so that the returns have practically amounted to a complete failure. During the 1939 season the Tinkurrin gravelly sand in one paddock was treated with a mixture of manganese sulphate and superphosphate as fertiliser, with the exception of a strip which received superphosphate only. The crop was a success, except on the strip without manganese, where it proved a complete failure as a large proportion of the plants died before reaching maturity. The appearance of the strip without manganese in early September is shown in Figure 1. By harvest time very little growth of wheat occurred on the affected strip.

Group 3—12 acres.

Patches of very gravelly soils which have not been differentiated.

Group 4—52 acres.

Sandy surfaced soil types which carry a mallee vegetation association and belong to soils characteristic of the mallee zone. The general profile features are a surface of 5-12 inches of grey to grey brown coarse or gritty sand with a cementy subsoil of yellow brown to olive grey gritty sandy clay; red mottlings show with depth, especially where waterlogging occurs. Some types show ferruginous gravel in the profile. Soil types of this group were not differentiated in the mapping.

Group 5—295 acres.

A series of mallee soils, apparently derived from gneiss, and characterised by an abundance of quartz grit, especially at the surface, a light grey surface

colour and calcium carbonate accumulation in a cementy subsoil of highly alkaline reaction. When mixed with distilled water the clay of the subsoil is slow to disperse but yields a very stable milky white suspension.

Two types within this series have been recognised on the basis of the depth of the surface sand.

The Kukerin sandy loam.

The profile of this type consists of a few inches of grey gritty sand on a cementy, grey yellow to yellow brown gritty sandy clay. Calcareous rubble occurs in the subsoil. It is described as a sandy loam as the shallow sandy surface is buried and mixed with the subsoil clay in the course of cultivation. During the summer months areas of this type are characteristically cracked on the surface, due to the contraction of the clay on drying out. In the virgin state this type carries a thick growth of stunted mallees (*Eucalyptus eremophila* and spp.), and appears to be related to the moort (*Eucalyptus platypus*) country further south. Portions of this type show salt patches, and, where salt appears, further damage has been caused as a result of the removal of the surface soil by wind action.

Table 3 gives details concerning representative profiles of the Kukerin sandy loam.

The Kukerin sand.

The Kukerin sand is similar to the Kukerin sandy loam but is characterised by a deeper layer of sand on the surface. A typical profile consists of 4-6 inches of grey loamy sand on a cementy subsoil of greyish yellow sandy clay; a certain amount of ferruginous gravel may be present. Below a depth of about 18 inches the clay is somewhat similar in nature but contains dense, hard, calcareous nodules. The properties of a representative profile of the Kukerin sand are given in Table 3.

TABLE 3.

PROPERTIES OF SOILS OF THE KUKERIN SERIES (GROUP 5).

(*Both sites are under cultivation*).

Serial No.	Depth.	Gravel.*	pH.	Salt (NaCl).	Description.
Kukerin sandy loam—	inches.	%		%	
3107†	0—2	13·3	6·7	Trace	brownish grey gritty sandy loam.
3108	2—5	15·9	7·4	·01	brown gritty clay loam.
3109	5—13	22·7	8·5	·03	brown gritty clay with ferruginous gravel at 11 inches.
3110	13—17	21·7	8·8	·04	brown gritty calcareous clay.
3111	0—2	7·3	7·4	·02	brownish grey gritty sandy loam.
3112	2—15	2·4	8·8	·03	pale yellow grey gritty sandy clay.
3113	15—20	17·2	9·0	·06	pale yellow grey gritty clay with calcareous nodules.
3114	20—25	33·8	9·0	·08	pale yellow grey gritty calcareous clay with dense calcareous nodules.
Kukerin sand—					
3072	0—4	2·6	6·4	Trace	grey loamy sand.
3073	4—9	17·0	7·5	Trace	greyish yellow cementy sandy clay with ferruginous gravel.
3074	9—18	8·8	8·3	·01	greyish yellow sandy clay with dense calcareous nodules.
3075	18—24	34·9	8·6	·01	similar—more calcareous nodules.

* Per cent. of the fine earth plus gravel. † The subsoil at this site is browner than normal and represents a variation within the type.

The soils of the Kukerin series usually produce fair returns of cereals but unless finishing rains are up to the average the occurrence of dummy heads seriously reduces the crop yield.

Group 6.—126 acres.

Apparently intermediate between Group 2 and Group 5 is a group of sandy and gravelly soil types which, in the virgin state, carry wandoo and related vegetation associations. These do not appear to be calcareous in the subsoil although they are apparently formed on the kaolinised horizon of the country rock. Three types have been recognised on the basis of profile characteristics.

Type 6A.

Type 6A is characterised by an accumulation of ferruginous gravel in the subsurface. The typical profile is as follows:—

0-6 inches, pale brownish grey sand with a little ferruginous gravel.

6-18 inches, greyish yellow gravelly sand with gravel increasing with depth.

Below 18 inches, light brown sandy clay.

Type 6B.

A sandy type in which the profile consists of up to 12 inches of grey gritty sand resting on a brownish yellow to yellow cementy sandy clay loam. A little ferruginous gravel may occur in the profile.

Type 6D.

Type 6D shows a deeper surface layer of sand and appears to be forming on an accumulation of sand washed from higher levels. The profile consists of more than 12 inches of grey to light grey gritty sand resting on a light greyish yellow sandy clay loam; red mottlings appear with depth.

Crops on soils of Group 6 are reported to be unthrifty; they do not stool well and usually develop a disease resembling root rot, more especially in a wet season. It is apparent that this soil type is of a very low fertility status.

Group 7.—19 acres.

Sandplain and related soils.

The general profile of the sandplain and related soils on this farm consists of a greyish surface sand resting on a yellow sand with ferruginous gravel in the subsoil. These are of minor importance in this instance and are of relatively low fertility status.

Summary and Conclusions.

A description is given of the principal soil types of a farm in the wheatbelt east of Wagin. On this farm some 25 per cent. of the area is covered by soil types which exhibit acute manganese deficiency symptoms in wheat and oats.

The principal soil type exhibiting manganese deficiency is named the Tinkurrin gravelly sand. Characteristic features are the ashy, powdery nature of the surface and the accumulation of ferruginous and quartz gravel in the subsurface layer. The subsoil is a yellowish brown sandy clay loam showing further clay accumulation with depth.

The soils exhibiting manganese deficiency are associated with the laterite horizon which consists of ferruginous gravel and quartz gravel coated with ferruginous material mixed with loose sand. This lies above the country rock which appears to consist of gneisses, the upper portions of which are more or less kaolinised.

Two main groups of soils have been recognised where the country rock has been exposed. One of these has been described as the Kukerin series, which is a light grey soil, rich in quartz grit. The other group of soils, described as Group 1, generally occupies the lower parts of the farm and appears to be formed on a hornblende gneiss. These are the most productive soils of the farm with respect to production of cereal crops. Four other soil groups of minor importance are described in the text.

The application of manganese sulphate at the rate of 14 lbs. per acre prevents the appearance of manganese deficiency of wheat or oats on the soil types deficient in available manganese. The manganese sulphate is applied mixed with the superphosphate.

Acknowledgments.

Grateful acknowledgment is made of the assistance of Mr. G. H. Burvill in the determination of the soil reactions reported.

The thanks of the authors are tendered to Dr. Dorothy Carroll, of the University of W.A., for the determination of the soil minerals.

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The Small Plague Grasshopper.

(*Austroicetes cruciata, Sauss.*)

WITH SOME NOTES ON EGG PARASITES OCCURRING IN WESTERN AUSTRALIA,

by

C. F. H. JENKINS, Government Entomologist.

In earlier publications of this Department this insect has been referred to as the Plague Locust, *Chortoicetes terminifera* (Newman 1924 and onwards), and the Plague Grasshopper, *Austroicetes jungi,* (Jenkins 1937).

At the Australian Grasshopper Conference held in Melbourne in 1938, the popular names given to various grasshoppers were discussed, and in order to obtain uniformity and avoid as much as possible further confusion, it was decided to use the name Small Plague Grasshopper for the loosely gregarious *Austroicetes cruciata* infesting the dry areas of Western Australia and South Australia, and the term Australian Plague Locust for the more strongly gregarious and migratory species *Chortoicetes terminifera,* often so troublesome in the Eastern States.

Both species occur in Western Australia, but, strangely enough, the Australian Plague Locust does not swarm in this State, or if so, on very rare occasions.

It has been shown that *A. jungi,* Brancsik, is a synonym of *A. cruciata,* Sauss (Key 1938).

Breeding Habits.

The grasshopper lays its eggs in almost any kind of soil, so long as it is compact and free from dense cover. Sandy soil and heavily grassed areas are avoided, as is dense forest and scrub country, but sparsely timbered land or narrow timber belts with bare open patches often afford good nesting sites. Roadsides, railway embankments, reserves, commonages and similar hard undisturbed localities are favourite breeding areas.

The female bores into the ground by means of hard chitinous valves situated at the end of the abdomen and a frothy substance is exuded as a lubricant during the operation and to form a lining to the egg pod.

A large number of males crowd around the female while she is laying and these clumps of yellow males are quite easily picked out during the laying period. About 20 eggs are placed in each pod. They are yellowish white in colour, slightly crescent shaped and about 3/16ths of an inch in length. The mouth of the egg pod is capped with soil cemented together by the frothy secretion exuded by the female and this cap is bodily lifted when the young hoppers emerge. The pod measures a little under ¾ in. in length.

Larval Stages.

When it first issues from the egg the young hopper is clothed in a tight fitting white sheath and the larva is known as the vermiform lava because it can only progress by means of worm-like wriggles. Almost immediately after hatching, the vermiform larva undergoes what is known as the intermediate moult and the little white casts can often be seen close by the holes from which the hoppers have emerged. The hopper is now said to be in its first larval instar and resembles the adult, save for the fact that it is very small and lacks wings. At first it is light in

colour, but very soon changes to a brown of varying intensity. Five larval instars are passed through, the insects changing from one to the other by means of an ecdysis or moult, until the final winged stage is reached.

Period of Emergence and Duration of Life.

The laying period varies according to seasonal conditions, but may extend from September to November. Only one generation occurs per annum and the progeny from the spring laying do not emerge until about the following July.

The pre-winged stage occupies approximately eight weeks, so that hoppers issuing at the end of July will be mature by the end of September, and as adults, they may live another six weeks.

Hatching may extend over a period of several weeks, the weather conditions having an important influence upon the rate of emergence. Due to this fact hoppers in various stages of development may be present in one area.

The grasshoppers display gregarious tendencies throughout life, clustering together, especially when dull or windy weather conditions are prevailing. In the later instars this gregarious tendency becomes more pronounced, and just before maturity the hoppers may be seen moving in bands or armies as if with a definite purpose in view.

NATURAL ENEMIES.

Egg Parasites.

Bombylid Fly.

Two egg parasites have so far been recorded from Western Australia, but by far the most common noted is a species of Bombylid Fly (*Crytomorpha flavis-cutellaris*).

The larvae of this fly are creamy coloured grubs, tapering at each end and when undisturbed they adopt a characteristic curled-up attitude with the head almost touching the tail. Each segment is clearly marked off from its neighbour by a yellowish line.

At this stage the larvae are apparently unable to move about and are found either ensconced in a grasshopper egg pod or curled up in the soil near same.

This insect has been collected in most of the grasshopper infested areas, but the larvae were first discovered and forwarded to this Department by Messrs. Hutchinson and Herbert from egg beds at Nungarin. Material from this locality later reached the Council for Scientific and Industrial Research and was described by Mary Fuller (1938).

The larval life is a long one, for grubs collected by the author in May and July when kept in the laboratory under room temperature emerged in December and January respectively, after a pupal period of about three weeks. The larvae were quite without food over that period during which they lay half buried in sand and were slightly moistened with water from time to time.

Adult.

The adult female (Roberts 1929) is about the size of the common house fly, but has a more globular shaped body. The head and thorax are dark in colour, and the abdomen yellowish, bearing a number of short, erect hairs.

Wasp Parasite.

For several years a careful search has been made for signs of a wasp parasite such as attacks the eggs of grasshoppers in the Eastern States and South Australia, but not until last year were any signs of such a wasp obtained.

Grasshopper eggs collected at Bindi Bindi in November 1939 and at North Westonia in May, 1940, produced a number of small wasps, kindly identified by Mr. A. P. Dodd as *Scelio chortoicetes*. This species has been recorded from the Small Plague Grasshopper elsewhere in Australia, but the present record is, as far as I am aware, the first for this State. The fact that it has not been found earlier, however, shows that it is not numerous and so, unfortunately, is not likely to play any significant part in the control of the pest.

General Description.

The adult female wasp is a tiny, shiny black insect, approximately 3/16ths of an inch in length. The legs are reddish brown, the antennae 12 segmented, and the fore-wings slightly clouded.

Egg Laying and Emergence.

The eggs of the Australian Plague Locust, *Chortoicetes terminifera*, in Eastern Australia are attacked by a wasp, *S. fulgidus*, closely resembling the local parasite, and it may be presumed that the method of attack is very similar.

"During egg laying, adult parasites are to be seen running about amongst the laying grasshoppers.

"Sometimes the parasites crawl beneath the thorax of the laying grasshopper and there await the completion of oviposition, when the parasite immediately makes its way down to the grasshopper eggs.

"If earth has fallen into the tunnel, the wasp uses all six legs to dig down until it reaches the dried secretion above the egg pod.

"The adult wasp makes an opening in one end of the egg and forces its way up to the surface of the soil, emerging through a small irregular hole in the soil. Where parasites are abundant, the surface of the ground may be marked by millions of these minute emergence holes which are in marked contrast to the large circular holes through which the young hoppers emerge from the soil." (Noble, 1938.)

Effect of Parasites.

As far as this State is concerned, neither of the egg parasites mentioned can be regarded as of very great economic importance. The heaviest infestation of egg pods with Bombylid larvae would not exceed 15 per cent, while the wasp parasite is as yet of nothing more than academic interest.

CONTROL MEASURES.

Preventive Methods.

Timber in its natural state presents quite an effective barrier against grasshopper infestation and wholesale clearing, and ring-barking for this reason should be deprecated, not to mention its effect upon the bird population and soil erosion. Every effort should be made to cultivate bare hard soil to render it unsuitable for egg laying. Known egg beds should be broken up as finely as possible to a depth of at least 2½ inches, thus fracturing the egg tubes and exposing the eggs to the elements and various natural enemies.

Cultural Methods.

The efficacy of ploughing and allied cultural methods as a means of grasshopper control has been viewed with suspicion by many authorities, but following the severe grasshopper plagues experienced in 1936, it was realised that

drastic methods would have to be adopted to stem the advance of the pest, and a comprehensive scheme was undertaken by the Western Australian Government. Since 1937 many thousands of acres have been broken up by mouldboard and disc ploughs, as well as by fixed tyne cultivators. Ample evidence of the effect of this work upon the resultant hopper population has been gained by comparing the progeny arising from cultivated and non-cultivated fields and by estimating damage done to crops adjoining broken and non-broken country. Where in a few cases the work has been done badly and clods and hard patches have been left, a number of hoppers have survived, but this only strengthened the contention that where the work is properly done effective control can be expected. Even after the grasshoppers have commenced hatching, mouldboard and disc ploughs and sundercuts have been used to advantage, as they turned over the soil and buried most of the hoppers, as well as the food supply of any which might have survived.

In the few cases brought to notice where cultivation was said to have been useless as a means of control, investigation showed that the work had been done late in the season when the hoppers were emerging, and with fixed tyne cultivators. These machines do not turn the land over but merely break it up, and so although for pulverising the surface and destroying egg-beds they are very effective, they are less useful at a later stage when it is necessary to bury the young hoppers and also the weeds which will supply the insects with the necessary energy to move from the fallowed ground.

The ability of young hoppers to live without food is remarkable, and under laboratory conditions they were found to survive for 10 days without nourishment, but upon moist blotting paper. After four days, however, they showed little activity, and it is unlikely that exposed to field conditions they would live more than a week or be able to travel far. Bearing this in mind, therefore, the importance of clean fallow, and where possible the advisability of working round and round a paddock so as to confine the hoppers to the centre, will be apparent.

Typical grasshopper country, north-eastern wheatbelt. [C.F.H.J.]

BAITING AND SPRAYING.

Non-poisonous Sprays.

As a contact spray, Burford's household carbolic soap and Sunlight soap were found to be very effective against hoppers up to the third laval stage. Burford's soap was used at the rate of 2½ ozs. to the gallon, and Sunlight soap at 2 ozs. to the gallon. Either should be mixed with hot water and applied while hot. The best time for spraying is early in the morning when the hoppers are sluggish.

Poison Spray.

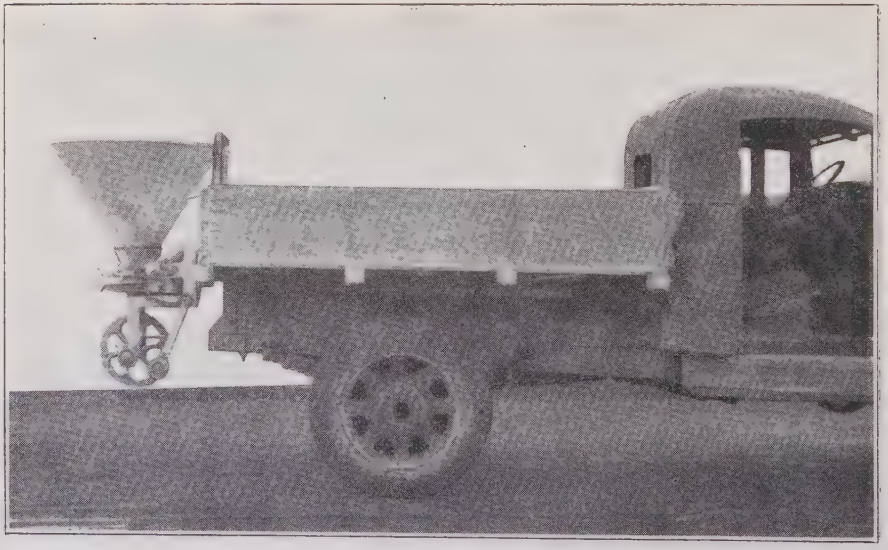
Arsenite of Soda, 1 lb.
Molasses, 4 lbs.
Water, 14 gallons.

This spray kills both by contact, due to the absorption of arsenic through the body integument of the insect, and also by the ingestion of sprayed foliage. It is particularly effective against young hoppers where green herbage is plentiful as is often the case early in the season.

Poison Bait.

Bran, 25 lbs.
Arsenite of Soda, ½ lb. (80 per cent. arsenious oxide).
Molasses, 6 lbs.
Water, 2½ gallons.

The above amount is sufficient to treat one acre. The arsenite of soda should be dissolved in water, likewise the molasses; the two should then be thoroughly mixed into the bran with sufficient additional water to make a moist crumbling mash. The amount of water required to bring this about may vary with different samples of bran but it is essential that the mixture is not allowed to become too wet, otherwise it will become lumpy and correct distribution will be impossible. It is best to thoroughly mix the ingredients and gradually add the water, rather than pour in the estimated quantity all at once, as an even mixture is difficult to obtain if the latter procedure is followed. Unless a broadcaster such as is des-



Bait-spreader attached to truck. [C.F.H.J.]
The chain drive to the backwheel has been removed.

Spreader showing revolving plate and veins for throwing bait.
[C. F. H. J.]

cribed below is to be used the bait is best laid by hand, the mixture being thrown into the wind with a flick of the wrist so as to ensure that it will fall in fine particles. Baiting should be done in the early morning before the hoppers have commenced feeding.

During the 1936 campaign in the Narembeen Road Board area, it was demonstrated that the poison bait could be effectively distributed per medium of super-spreaders. Two of these machines were brought into use on the property of Mr. W. N. Hedges. They were mounted on motor lorries and driven by a cog chain connected to the back wheel of the motor. The distribution of the bait by this means assured that it was scattered in the necessary fine particles, lumps being impossible. Mr. Hedges also devised a means of mechanically mixing the baiting ingredients.

This consisted of a circular drum or tank, which rotated about an axle fitted with a number of fixed arms or agitators. The tank was rotated by a belt attached to a small motor. By the use of these methods, much manual labour and man-handling of the baiting material is eliminated. In subsequent campaigns broad-casters have been used in almost all districts with great success and have proved themselves the most effective means of baiting large areas of country.

Power driven bait-mixer. [W.N.H.]

Danger to Stock.

Lumpy bait is a constant menace to stock just as long as the lumps remain. If the bait is laid carefully there is little or no danger to stock, but as a precaution it is advisable to remove stock from poisoned paddocks for a fortnight or three weeks. Experiments conducted by the New South Wales Department of Agriculture have shown that where the spray is used, no danger to stock is incurred even if they are allowed immediate access to treated herbage.

Mixing Precautions.

When mixing arsenical solutions, care should be taken to keep the hands as free from the substance as possible, otherwise sores may result. Smearing the hands with grease of any kind before commencing operations will greatly minimise this danger. All receptacles should be carefully washed after having been used for mixing purposes.

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M. T. Padbury Trophy Wheat Yields Competition.

I. Thomas, Superintendent of Wheat Farming.

This competition, which was for a period of 10 years, commencing with the 1930-31 season, was made possible by a generous donation by Mr. M. T. Padbury, a pioneer farmer in the Moora district. The trophy consists of a handsome jarrah shield having a raised oval centre carrying all the silver ornamentation and including the inscription "The M. T. Padbury Trophy for the Greatest Yield of Wheat per inch of Rainfall during Growing Season."

Under the conditions of the competition, the trophy is to be awarded to the competitor who obtained the greatest mean average acre yield per inch of growing period rainfall, computed from the results of the five seasons in which the competitor obtained his highest acre yield per inch of growing period rainfall. During the period of the competition, each annual winner, besides having his name engraved on the shield, was presented with a replica of the trophy.

The conditions under which the competition was conducted were as follow:—

1. The competition will commence with the 1930-31 harvest and continue for a period of 10 years. At the end of that period the trophy will be awarded to the competitor who has taken part in the competition for at least five years, and who obtains the greatest *mean* average, acre yield per inch of rainfall during the conventional growing period. The mean average yield will be computed from the *results* of the five seasons in which the competitor produced the *highest acre yield per inch* of rainfall during the growing period. In the event of a tie the competition will continue between the leading competitors until an advantage is gained by one of them.

2. The conventional growing period for any year will be that decided upon and announced by the Royal Agricultural Society. For the first year and until further notice it has been decided that it will be from May 1st to October 31st, inclusive.

3. Until the end of the competition the trophy will be in the custody of The Royal Agricultural Society, and will be displayed at any agricultural exhibition held by that society.

4. Each year the competitor who obtains the best average acre yield per inch of rainfall during the conventional growing period will be awarded a replica of the trophy. His name will also be inscribed upon a small shield affixed to the trophy.

5. The rainfall upon which the award will be made will be determined by the Commonwealth Meteorologist from the district records, and his decision in this matter will be final.

6. The competition will be limited to those farmers who harvest at least 200 acres of wheat for grain. Where a competitor is financially interested in the crops grown on one or more farms, he will be required to supply details regarding the production and marketing of the crops on same, and though usually the award will be made upon the results from the farm nominated by the competitor, yet The Royal Agricultural Society may require that the crops on these farms be included in the competing area.

7. The average yield will be ascertained from the total area—including self-sown crops—harvested for grain, and determined from the actual amount of wheat sold as shown by the delivery dockets, plus the amount retained for seed, for home use or for any other purpose.

8. The method of judging will be as follows:—At a convenient time the area harvested for grain will be measured and the quantity of wheat on hand ascertained. On or before January 31st, the farmer will be required to furnish the judge with a sworn declaration as to the quantity of wheat sold from the competing holding or holdings, and the amount retained for seed and other purposes; the statement regarding the amount sold to be supported by agents' dockets. The judge, after satisfying himself as to the correctness of this statement, will compute the average yield per acre per inch of rainfall during the growing period from the information received.

9. The judge will be appointed by the Under-Secretary for Agriculture, and his decision will be final.

10. Nominations for this competition will be received by the Royal Agricultural Society up to the 31st October each year.

The winner of the 1939-40 competition was Mr. P. Strange, of Yarding, with an average of 2 bushels 6 lb. per inch of rainfall from an area of 304 acres. Mr. N. A. Scadding, of Kulin, filled second place with 2 bushels 1 lb. over 545 acres, and was followed by Mr. E. W. Prowse, of Doodlakine, with 1 bushel 47 lb. over 492 acres.

As a result of the more favourable rainfall during the season, despite the dry September, the actual average yields per acre for the seven competitors was higher than for the preceding year, being 21 bushels 42 lbs. per acre compared with 17 bushels 19 lbs. per acre in 1938, but the average yield per inch of rainfall during the growing period was lower, being 1 bushel 44 lbs. as compared to 2 bushels 18 lbs. the previous year.

The detailed results for the 1939-40 season are given in the table below:—

Competitor.	Address.	Rainfall during Growing Period.	Area Harvested.	Yield.					
				Gross.		Average per Acre.		Average per Inch Growing Period Rainfall.	
		Points.	acres.	bus.	lb.	bus.	lb.	bus.	lb.
Strange, P.	Yarding	1,113	304	7,115	48	23	24	2	6
Scadding, N. A.	Kulin	1,360	545	14,844	12	27	14	2	1
Prowse, E. W.	Doodlakine....	1,161	492	10,830	49	22	1	1	57
Bremner & Sons, J. R.	Corrigin	1,327	919	21,685	54	23	36	1	47
Nottage, R. B.	Tammin	1,320	594	13,102	25	22	3	1	40
Barr, D. F.	Shackleton	1,154	575	9,440	33	16	25	1	25
Atkins, J. L.	Miling	1,605	812	15,055	47	18	32	1	14

The finalising of the results for the 1939-40 season brings this competition to a conclusion, and the following table shows each annual winner, together with their location and average yields:—

Year.	Competitor.	Address.	Yield.			
			Average per Acre.		Average per Inch Growing Period Rainfall	
			bus.	lb.	bus.	lb.
1930	Williams, F. A.	Mangowine	27	5	3	23
1931	Atkins, J. L.	Jouerdine	19	27	3	0
1932	Butcher, O. J.	Pithara	31	12	2	42
1933	Atkins, J. L.	Jouerdine	22	47	3	39
1934	Atkins, J. L.	Jouerdine	18	49	4	29
1935	Moore, Hon. T.	Indarra	24	11	4	6
1936	West, F. C.	Toompup	28	52	2	56
1937	Jones, R. M.	Shackleton	21	42	3	16
1938	Moore, Hon. T.	Indarra	23	54	4	9
1939	Strange, P.	Yarding	23	24	2	6

During the 10 years of the Competition, there were 69 participants, but of these only 12 competed for the stipulated five or more years.

In the table hereunder are set out the mean average results computed from those of the five seasons in which the 12 finalists obtained their highest acre yield per inch of growing period rainfall, together with the total number of years in which they competed.

Final Award and Results for those Competitors competing for Five or more Years.

Average Results for Best Five Years.

Competitor.	Address.	Average Area Harvested.	Yield.		No. of Years Competing.
			Average per Acre.	Average per Inch Growing Period Rainfall.	
		Acres.	bus. lb.	bus. lb.	
Moore, Hon. T.	Indarra	255·2	27 37	3 26	6
Atkins, J. L.	Jouerdine and Miling	474·5	19 54	3 1	5
Nottage, R. B.	Tammin	354·5	27 45	2 51	5
White, R. H.	Gnowangerup	274·4	28 30	2 30	5
Strange, P.	Yarding	349·8	23 17	2 26	6
Manuel, C. J.	Mukinbudin	416·1	18 7	2 26	5
Stewart, W. B.	Gnowangerup	235·0	27 42	2 22	5
Bremner & Sons, J. R.	Corrigin	955·2	20 47	2 21	10
Scadding, N. A.	Kulin	480·7	25 41	2 20	7
Creagh Bros.	Nungarin	1,019·6	17 53	2 19	5
Prowse, E. W.	Doodlakine	549·6	17 53	2 13	5
Barr, D. F.	Shackleton	511·1	17 38	1 56	5

Though the majority of these finalists were located in the more eastern wheat belt, they included entrants from the Great Southern and the Northern districts.

In determining the ultimate winner, the mean was computed from the results of the five best seasons for each finalist by averaging the acre yields per inch of rainfall for those five seasons.

The winner of the trophy was the Hon. T. Moore, M.L.C., of Indarra, who obtained the very excellent average of 3 bushels 26 lb. per inch of rainfall, and was closely followed by Mr. J. L. Atkins, formerly of Jouerdine, with 3 bushels 1 lb. Mr. R. B. Nottage of Tammin was a close third with 2 bushels 51 lb.

The performance of all finalists was highly meritorious having special regard to the seasonal conditions during the period under review. It will also be noted from the above table that only one competitor, Messrs. J. R. Bremner & Sons of Corrigin participated every year. This competitor obtained the excellent mean average acre yield of 2 bushels 6 lb. per inch of rainfall and an actual average yield per acre of 20 bushels 56 lb. for the *whole ten year* period from an average acreage of 942 acres.

During the 10-year period of the competition, the average yield per acre of all 69 competitors was 21 bushels 43 lb. The State's average yield for the same period was 11 bushels 36 lb.

With the close of this Competition a brief review of the farming and cultural practices generally adopted by the competitors is of interest.

A summary of the cultural practices, etc., of the finalists, from whom information was available, is given in the accompanying table:—

CULTURAL DETAILS OF FINALISTS.

Competitor.	Vegetation and Soil.	Implements, etc.	Cultural Practices.	Seeding.	Varieties.	Other Crops.	Sheep.
Moore, Hon. T., Indarra	York gum, jam Red brown loam overlaying clay subsoil	Disc-cultivating plough, spring-tyne cultivator, combine cultivator drill Horses	3-year rotation, early Winter fallowing, spring cultivation and before seeding; in summer only when necessary	Crops mainly seeded dry, little weed trouble due to clean fallow; graded and pickled seed 45 lb. per acre; super 100 lb. per acre	Bencubbin up to 1934, Merredin, Ranee and Dundee	Oats	Yes
Atkins, J. L.— Jouerdine	Salmon gum gimlet Heavy clay	Tractor, mouldboard and disc cultivating ploughs, spring-tyne cultivator, combine-cultivator drill	Early winter fallowing, fallow disturbed as little as possible on account of setting and erosion	Seeded April-May according to variety; graded and pickled seed 37–40 lb. per acre, super. 100 lb. per acre	Bencubbin, Gluyas Early, Noongaar		
Miling	York gum	Disc-cultivating plough, spring-tyne cultivator, combine-cultivator drill	Early winter fallowing, spring cultivation and prior to seeding with combine	Seeded May; graded and pickled seed 53 lb. per acre, super. 112 lb. per acre	Bencubbin, Gluclub; Noongaar not suitable in this district	....	Yes
Nottage, R. B., Tammin	Gimlet Clay and loam	Disc-cultivating plough, scarifier, rigid-tyne combine-cultivator drill, Tractor	3-year rotation, early winter fallowing with disc, 2nd working with rigid-tyne cultivator and again before seeding, light harrows on drill	Seeded mid-April-May; graded and pickled seed 45 lb. per acre, super. 90 lb. per acre	Bencubbin, Noongaar, Totadgin	Oats—partly for control of Take-all	Yes
Strange, P., Yarding	Salmon gum, gimlet, York gum, jam and scrub Mixed soil types, some wodjil	Disc-cultivating plough, scarifier, combine cultivator drill Horses	Six-year rotation, fallow wheat fallow wheat oats pasture; early winter fallowing with disc; for some years a second discing given, latterly used scarifier; cultivated prior to seeding	Seeded mid-April-late May; graded and pickled seed 50 lb. per acre, super. 100 lb. per acre	Gluclub, Bencubbin	Oats for grain, hay and green feed; small area Sudan Grass	Yes
Manuel, C. J., Mukinbudin	Salmon gum, gimlet and morrell Heavy red clay	Disc-cultivating plough, spring-tyne cultivator, disc drill till 1933, combine cultivator drill Horses till 1934 then horses and tractor	2-year rotation, winter fallowing; spring-tyne cultivated in spring and prior to seeding	Seeded late April-May; graded and pickled seed 45 lb. per acre, super. 80 lb. per acre	Gluyas Early, Totadgin	Oats	Yes

Stewart, W. B., Chowangerup	York gum, morrell, salmon gum, jam, mort, mallee. Red loam, grey loam, some clay	Mouldboard plough, spring-tyne cultivator, spring-tyne combine, cultivator drill. Horses.	Rotation—Fallow wheat 2 or 3 years pasture, sometimes includes crop of oats or lucerne or both; early winter fallowing (mouldboard); spring-tyne cultivated twice in spring, after Autumn rains and before seeding with combine	Seeded mid-May-June; graded and pickled seed 48 lb. per acre, super. 112 lb. per acre	Yandilla King and Nabawa during early years, then Bencubbin and Free Gallipoli, now Bencubbin and Nabawa	Oats, barley, lucerne; wimmera rye with cereal crops	Yes
Bremner & Sons, Corrigin	York gum, salmon gum, morrell, gimlet, am and mallee Heavy clay, light loams and sand	Scarifier, spring-tyne cultivator, combine-cultivator drill, light harrows Horses and tractor	Mainly 2-year rotation, now intending to widen rotation considerably, early winter fallowing with scarifier, two further scarifyings before spring, spring-tyne cultivation before seeding	Seeded during April-May; graded and pickled seed 50 lb. per acre, super. 145 lb. per acre	Ghyas early during early years, now mostly Bencubbin	Oats, barley . .	Yes
Scadding, N. A., Kulin	Tea-tree, morrell, gimlet Heavy and light land	Disc-cultivating plough, spring-tyne cultivator, combine cultivator drill Tractor	Two-year rotation till 1936, then widened considerably: early winter fallowing. Spring-tyne cultivated in spring and prior to seeding	Seeded mid-April mid-May; graded and pickled seed 60lb. per acre; super. 120lb. per acre	Bencubbin, Gluchub, Totadgin, Pusa IV.	Oats	Yes.
Creagh Bros., Nungarin	Salmon gum, gimlet, whitegum, mallee and boree Heavy clay, clay loam, sandy loam	Disc-cultivating plough scarifier, spring-tyne cultivator, combine cultivator drill Tractor	Three-year rotation; fallow, crop, pasture; ploughed June, July, August; scarifier or spring-tyne cultivation in Spring and before seeding	Seeded all on fallow early May early June; graded and pickled seed 45lb. per acre; super. 90lb. per acre	Bencubbin, Noongaar, Ghyas Early, Carrabin	Oats; small area top-dressed	Yes.
Prowse, E. W., Doodlakine	Salmon gum, gimlet and scrub Mainly heavy land	Disc-cultivating plough scarifier, combine cultivator drill Horses and tractor	Three-year rotation during early years. Altered to 3-year rotation; light land, 4-year; fallow, wheat, oats fed off, pasture; early winter fallowing with scarifier in 2-year rotation; disc after being under pasture; cultivated in Spring and prior to seeding	Seeded late April-May; graded and pickled seed 45lb. per acre; super. 100lb. per acre	Gluchub, Bencubbin, Totadgin, Noongaar	Oats . .	Yes.
Barr, D. F., Shackleton	Gimlet, salmon gum, tea-tree, mallee and scrub Heavy and light land	Mouldboard, heavy disc cultivating plough, scarifier, spring-tyne cultivator, combine cultivator drill, light harrows Horses and tractor	Two-year rotation in early years, now 3-year; early winter fallow; Spring-tyne cultivated in Spring and prior to seeding	Seeded late April-May-June; graded and pickled seed 45lb. per acre; super. 90lb. per acre	Bencubbin, Gluchub, Noongaar		Yes.

The farming methods adopted closely follow the results of the lessons to be learnt from the experiments conducted at the several Research Stations. The application of these varied according to the rainfall, but the following general principles apply to both the heavier and lighter rainfall areas:—

(1) Plant the wheat crop on land which has been fallowed.

(2) Carry out the initial operation of fallowing (ploughing) during the early winter months to a depth of from 3-4 inches.

(3) Cultivate the ploughed land to a full depth of ploughing, preferably with a tyne implement, during the spring months, to form a soil mulch and destroy weed growth.

(4) Depasture sheep on the area to be fallowed, during fallowing and after being fallowed, to control weed growth.

(5) Disturb the fallow as little as possible during the summer months, except when necessary to destroy weed growth and maintain the mulch.

(6) Cultivate following upon rains in Autumn, prior to seeding; this cultivation should not be deeper than is sufficient to efficiently destroy weed growth, otherwise the consolidation of the seed-bed will be interfered with.

(7) Use clean graded seed wheat of suitable maturing and disease-resisting varieties. For the prevention of the disease Ball Smut, the seed requires to be treated with Copper Carbonate or other suitable fungicide.

(8) Plant at the correct depth, namely 1½-2 inches, on a well consolidated seedbed.

(9) It is essential that the different maturing varieties be planted at the correct time in accordance with their seasonal maturity, i.e., the late maturing varieties early in the season, followed by the mid-season maturing varieties, and these followed by the early and very early maturing varieties.

In the lower rainfall areas seeding should be completed by the end of May, and in the more favoured rainfall areas not later than the first or second week in June.

(10) The rate of seeding in the lower rainfall areas is approximately 45 lb. per acre, and the wetter districts up to 60 lb. per acre, together with a liberal application of superphosphate, up to 1 cwt. on the heavier soils, and from 120 lb. on the lighter and sandier types.

(11) The crop rotation on the farm should be such that will enable the maximum number of stock to be carried, and which will improve and conserve the fertility of the soil and assist to control diseases such as flagsmut and take-all, and in this direction what is known as the modified three-year rotation is recommended—crop and fallow for a period of 6 years, followed by a period of pasture of 4-6 years. This rotation can be modified to include more pasture years, depending upon the total area of the farm and the area under cereal crop. When planting the crop, prior to the land being allowed to return to pasture, pasture seeds, preferably of leguminous species, should also be sown so as to provide improved pasture in subsequent years.

(12) It cannot be over-emphasised that when carrying out the various cultural operations, they should be carried out at the right time, the job done thoroughly, and in the most efficient manner. To do this, the implements must, at all times, be maintained in good order.

A perusal of the results obtained by the competitors show that the yields obtained were highly meritorious, and many of the participants attribute their success in achieving such to closely adopting and carrying out these basic principles.

More Pigs in the North-Eastern Wheat Belt.

W. M. Nunn, Agricultural Adviser, Kununoppin.

For some years the comparatively recently opened up North-Eastern wheat belt remained a purely wheat growing area. There was a natural trend, of course, toward mixed farming, but while satisfactory returns were being obtained from wheat growing, the development was slow and the tendency everywhere was to produce more and more wheat rather than to provide conveniences for the running of more stock.

With the recent run of dry seasons and of low prices, returns from wheat growing have been less satisfactory and the development of mixed farming methods has been considerably hastened. The progressive farmer is not content to rely on returns from wheat alone. He is giving more and more time and attention to the building up and management of a flock of sheep, and in many instances to the establishment of a herd of pigs.

There is no doubt that sheep are really essential to the successful management of the farm. They not only provide extra income from wool and lamb returns; they supplement farm workings in the cropping programme and are necessary to every intelligent system of crop rotation. With the assistance given by the Agricultural Bank in recent years practically all farmers have made, or are about to make, a start with sheep.

Pigs also are profitable and those who have their wheat cropping and their sheep management nicely co-ordinated and who can provide the labour and conveniences for the correct management of a herd of pigs, should give careful thought to the possibilities offered by the export bacon market. We do not know what price to expect for the coming season's wheat, but anticipations with regard to export bacon prices, however, are considerably brighter. The day is gone when local supplies affected prices and we have a steady demand for export bacon carcases at prices guaranteed by the British Government. Wheat is a satisfactory feed for pigs, if suitably supplemented, and it is far more profitably disposed of by turning it into bacon than by selling it as grain.

Experiments carried out at Muresk Agricultural College in 1938 by H. J. Hughes and C. R. Dixon and published in the March, 1939, issue of this Journal (1), arrived at very interesting figures regarding the costs of feeding pigs on wheat with protein supplemented in several different forms. Using these figures as a basis of calculation the Superintendent of Dairying has shown in recently delivered lectures that at the present guaranteed prices for export bacon, wheat should return 7/- gross per bushel to the grower who sells it as bacon. The net return would vary according to the charges made for labour, capital expenditure, rent and whether the pigs were bought or bred on the farm.

It is not intended here to set out proof as to the correctness of this figure based upon experimental results obtained in 1938. The prices of protein supplements have altered slightly since then and will alter again: the price guarantee for bacon may be altered when reconsidered in June, but it is suggested that even if the price for bacon pigs were lowered by as much as twopence per pound, wheat would return something like 4/6 or 5/ per bushel gross if sold through the pig.

There are perhaps more pitfalls in pig-breeding than in any other branch of mixed farming—particularly in those districts, for which this article is intended, where conditions are not naturally suited to pigs and where the be-

ginner is surrounded by beginners. The farmer frequently buys pigs because he feels there is money in them. He has perhaps never seen a correctly laid out and managed pig farm and soon, as a result of improper sanitation, mismanagement or poor feeding methods, his pigs are in unthrifty condition: they are unprofitable, and his venture has become a failure.

This article is intended firstly as an urge to wheat-belt farmers to go in for pigs—they are profitable—and secondly as a warning to them that the job must be done properly if it is to be attended by success. Farmers are encouraged to write to the Department of Agriculture for Leaflet No. 496 (2), which deals more fully with the breeding and management of pigs, but some important factors are summarised below to assist beginners in steering clear of the many pitfalls open to them.

Yards.

It is essential that the pig be provided with clean, roomy and warm quarters. Avoid the old method of imprisoning the animals in poky sties which cannot be kept clean. Almost every ailment the pig is capable of contracting is aggravated by unclean conditions, and if any trouble of an infectious nature is introduced, it is under these conditions that its spread is most devastating. Provide them with roomy yards on a well-drained site with warm draught-proof shelters for sleeping.

Above all, see that the yards are ready before the pigs are obtained or you may never have time to go ahead with the construction.

Type of Pig.

The Tamworth and the Improved Berkshire have consistently shown themselves to be most suitable for wheat-belt conditions, but whatever breed is used it is essential to select animals which conform to the bacon type required by the English market if export carcases are to be produced. The carcase required is the leaner type showing good length, light shoulder, well developed lengthy ham, light jowl and small head. Avoid the old fashioned, short, dumpy pig, with its short, overfat ham, short side, heavy fat shouder and very fat jowl.

Feeding.

Wheat is, of course, the basis of the ration throughout the wheat belt, but it must be supplemented with some form of protein—a muscle and bone-forming material which is present in wheat but not in sufficient quantity, and with some form of calcium—the only essential mineral requirement which is not supplied by wheat. Pigs fed on wheat alone very soon show evidence of protein deficiency. Troubles at farrowing, small litters, litters born dead and stunted growth in survivors are ills that can often be traced to protein deficiency. Even if such extremes are avoided, the pig which is fed on wheat alone stands very little chance of producing a good bacon carcase because, with insufficient protein, the growth of the body is handicapped; fat is laid on at the expense of lean meat and bone, and the short, fat type of carcase, which is not wanted by the market, is the result.

Where skim milk is not available, meat-meal is the most economical protein supplement. To grow good bacon with wheat as the main foodstuff see that you include about 12 per cent. of meat-meal in the weaner's ration; decrease this to 10 per cent. by the time the animal is about 50 lbs. live weight, and after another month when the pig is about porker weight, gradually introduce a little

oaten chaff and increase this up to about 10 per cent. The effect of the chaff is to prevent fat being laid on too heavily in the later stages, and recent experiments and practical experience have shown that it greatly improves the quality of the carcase.

Calcium can easily be supplied by adding 1-2 per cent. of bone-meal or ground limestone to the ration or by adding slaked lime to the drinking water.

The above rations are worked out on the assumption that little or no green feed is available. Pigs do best of all on grazing and if it could be provided most of the troubles now being met by beginners in the wheat areas would be avoided. It is particularly desirable that some green feed or silage should be provided for sows with litters, as it greatly increases lactation and so the health and growth of the young pigs.

Disease.

No discussion which deals with pigs, however briefly, is complete without some mention of the possibility of introducing disease to the herd. The pig is susceptible to so many ailments—swine plague in particular is so common throughout these areas at present—that the farmer should be very careful when purchasing new stock. If he does not know from personal knowledge of the former owner's stock that his purchases are healthy, he should keep them isolated until he is confident that they are not carrying disease which might spread to his other pigs.

Conclusion.

The most profitable way of marketing wheat under present conditions is to feed it to pigs and sell it as export bacon. The indications are that this state of affairs will continue—war or no war—for some time to come. Certainly the wheat farmer lacks certain advantages possessed by the dairy farmer with regard to pastures and supplies of skim milk, but it has already been shown by men who are going into the job thoroughly that pigs can be satisfactorily and profitably run even without these advantages. Furthermore, the dairyman has to buy his grain feeds; the farmer grows them and his concern is to sell to the best advantage.

If attention is given to the above briefly mentioned considerations with regard to management and feeding, and it is remembered that field officers of the Department of Agriculture are ready and eager to assist should trouble arise, no farmer should have any doubt as to the ultimate success of his venture in pigs.

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